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The plan to send water bears to a galaxy far, far away...

Health
We need to talk about postnatal depression in dads

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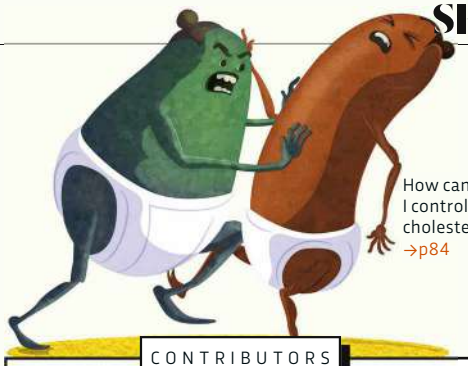

How can I control my cholesterol? →p84

FROM THE EDITOR

Are we alone in the Universe? It's probably the most profound question science has yet to answer. But so far the search for extraterrestrial life has only found shadows.

However, over the next few years the search for alien life is about to seriously ramp up. All being well, the most powerful telescope ever built, the James Webb Space Telescope, will start sending back images to Earth by the end of March. Its sensors and tech will let scientists take a closer look at Earth-like exoplanets than ever before. In 2023, the Vera Rubin Observatory in Chile will open its shutters to survey the stars. This telescope will have largest camera of any ever built and will enable astronomers to map and catalogue the Universe in unprecedented detail. And a little closer to home, the Rosalind Franklin rover will land on Mars as part of the ExoMars mission, which will try to answer, once and for all, whether life has ever existed on Mars.

But it's not all about new tech. A handful of scientists have also hatched a plan to look for alien life in a completely new way. Instead of searching for signals, for traces of the ingredients for life, or the by-products of living creatures, these astronomers think we ought to be searching for something altogether bigger and therefore easier to find: alien technology. It sounds like the stuff of science fiction, but there's some serious science behind it. Head to p52 to find out whether there's a smarter way to find ET.

Daniel Bennett

Daniel Bennett, Editor

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COVER: MAGIC TORCH THIS PAGE: BBC X2, ALAMY, DANIEL BRIGHT

ON THE BBC THIS MONTH...

The Doctor Will See You Now
This new series presented by Kate Garraway (right) brings augmented reality into the doctor's office. Patients journey through their own bodies using AR to help them better understand common medical conditions.
BBC Two and iPlayer
Check *Radio Times* for details

Ramblings
Across nine episodes, Clare Balding explores rambling routes around the UK and meets the people who take trekking to the next level.
BBC Radio 4
Thursdays, 3pm

Dynasties II
Returning this month is the fantastic animal documentary *Dynasties II*, presented by Sir David Attenborough. Four episodes will explore the remarkable lives of the elephant, cheetah, puma and hyena.
BBC One
Check *Radio Times* for details

CONTRIBUTORS

STEPHEN LANTIN
Water bears are one of the toughest creatures on the planet, which is why Stephen wants to send a herd of them to interstellar space. →p26

DR STUART FARRIMOND
Supermarkets are loaded with plant-based alternatives to meat, but are they any good for your health? Food scientist Stuart investigates. →p30

DR MICHELLE DROUIN
Is modern life and tech driving us apart? Psychology professor Michelle examines the consequences of a loss of intimacy in everyday life. →p66

KIMBERLEY WILSON
As a psychologist who's worked in prisons and a *Great British Bake Off* finalist, Kimberley is the perfect person to explore how food and mental health is linked →p72

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A series of prison studies have raised interesting points about whether the food we eat could affect how violent or aggressive we are.

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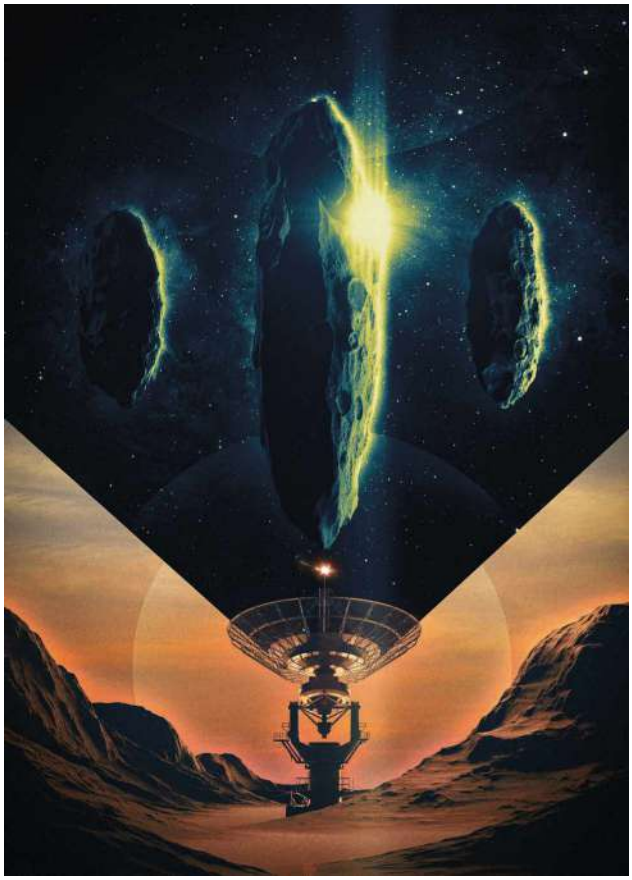
ARE WE ALONE IN THE UNIVERSE?



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DR MICHELLE DROUIN

"YOU ARE NOT AFRAID THE AI IS GOING TO YELL, OR BERATE YOU, OR TELL YOU THAT YOU'RE NOT WORTHY. IT'S JUST THERE TO SUPPORT YOU"

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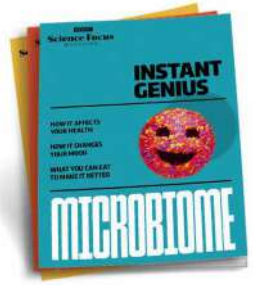

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A collection of the most important ideas in science and technology today. Discover the fundamentals of science, alongside some of the most exciting research in the world.

EYE OPENER

Dinosaur embryo

GANZHOU, CHINA

Meet Baby Yingliang – a perfectly preserved dinosaur embryo. Discovered in Ganzhou, China, this incredible specimen is at least 66 million years old, and was likely preserved in such exquisite detail by a sudden mudslide that buried the egg. But what makes this specimen even more remarkable, is how the embryo is positioned.

This baby oviraptorosaur (a type of theropod dinosaur) is in the same position as a chicken about to hatch, and it's the first time this behaviour has been recognised in dinosaurs. Known as 'tucking', a chick will tuck their head under the right wing for stability, allowing them to crack open the shell with their beak. Curling up like this is critical for a successful emergence, as palaeontologist Prof Steve Brusatte explains: "This little prenatal dinosaur looks just like a baby bird curled in its egg, which is yet more evidence that many features characteristic of today's birds first evolved in their dinosaur ancestors."

GETTY IMAGES

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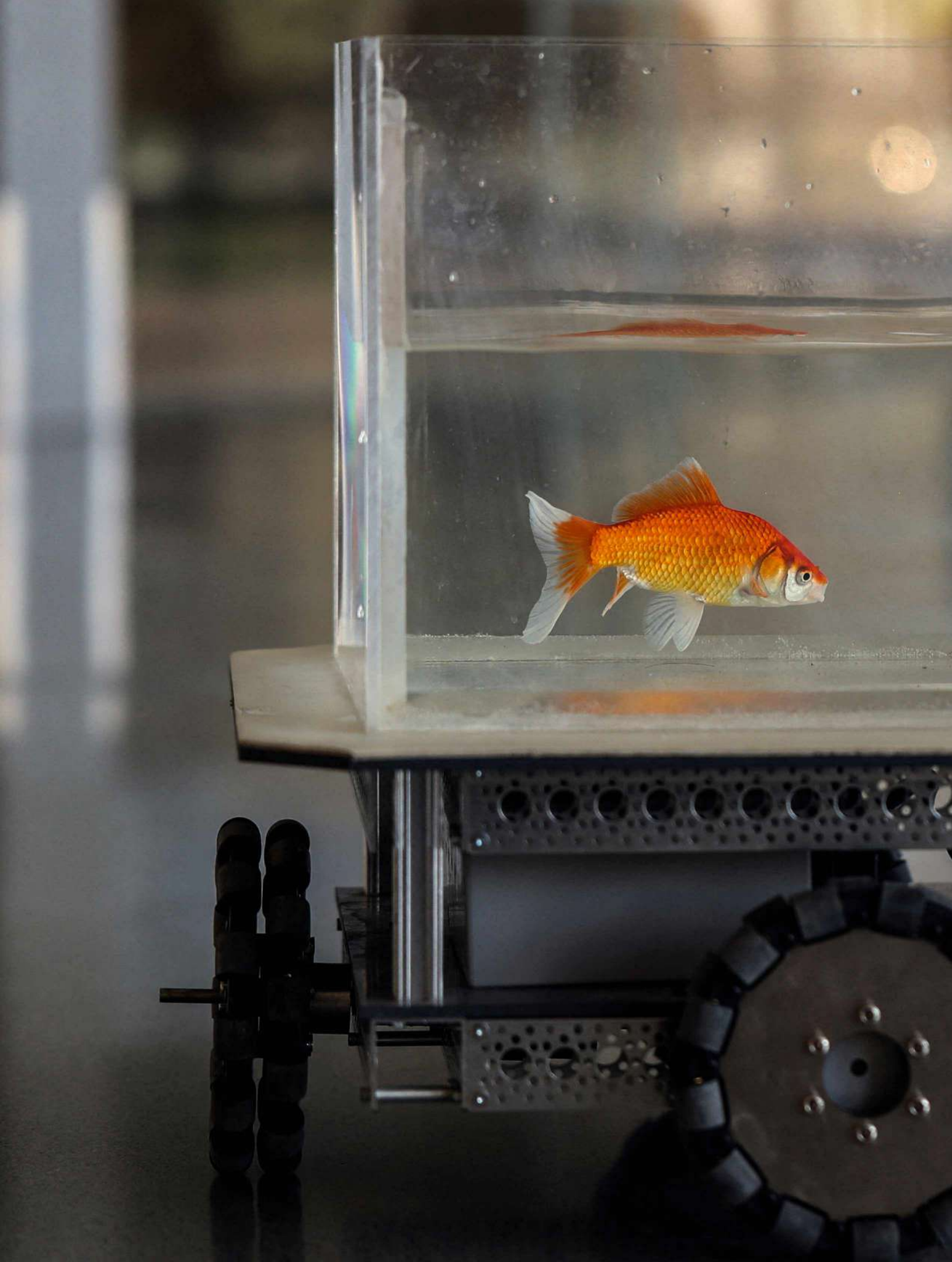

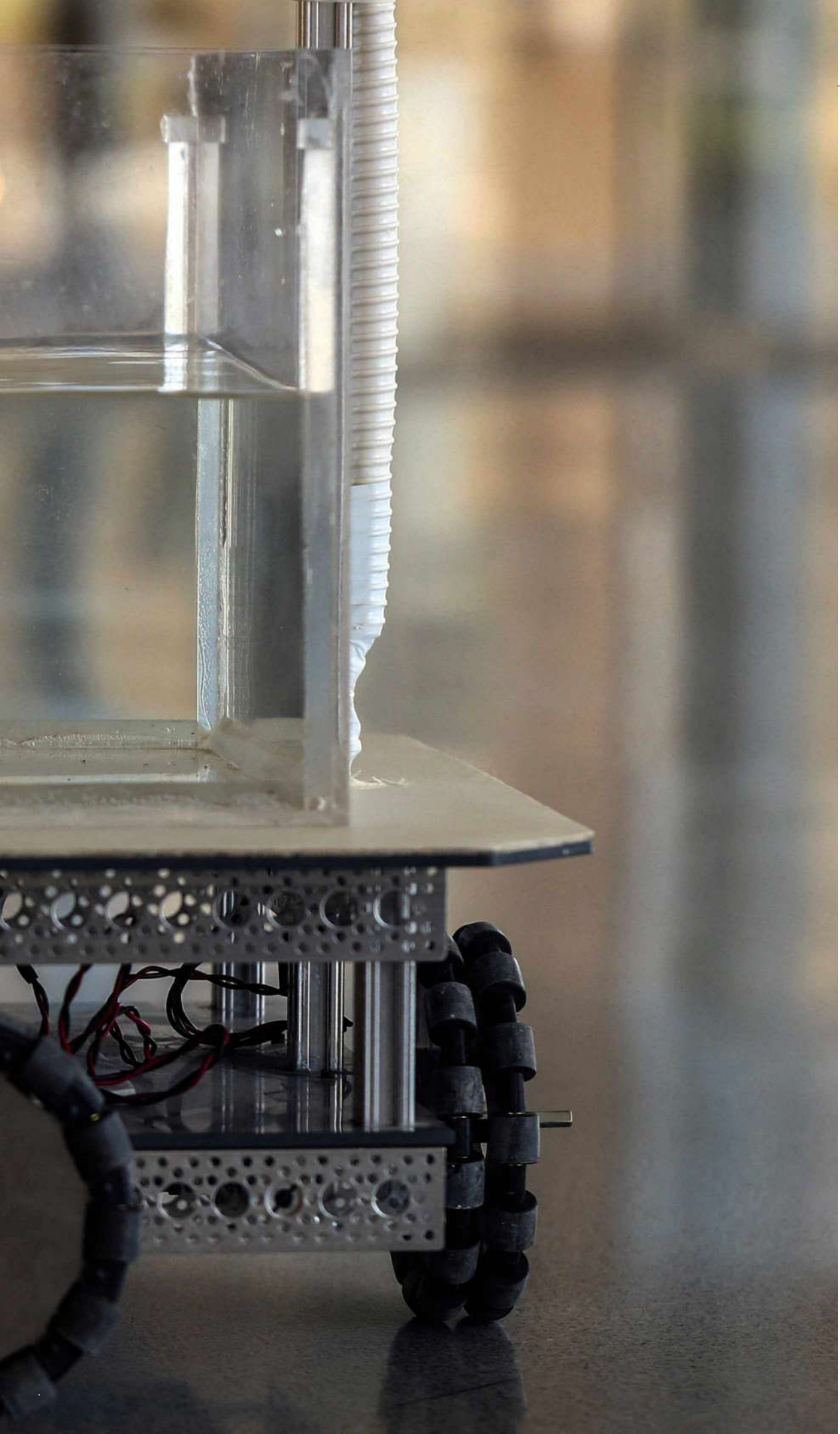

EYE OPENER

Dude, where's my tank?

BEERSHEBA, ISRAEL

As it turns out, goldfish can take to driving a car like a duck to water.

A team at Israel's Ben-Gurion University taught six fish to move a wheeled tank towards a target, in return for a treat. In each case, a camera was positioned above the tank, and the fish was taught to 'drive' by moving its body around the tank. The camera monitored the fish's movements, streaming the images to a computer, which then moved the wheels of the 'fish-operated vehicle' in a particular direction.

Aside from making fairground games more difficult, the research has implications for a future exploring among the stars, says study author Dr Ohad Ben-Shahar. Proving a fish can drive on land could lead to insights in helping astronauts navigate in an unfamiliar environment. "We [should] definitely shoot for that," he says.

REUTERS

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EYE OPENER

With love, from Mars

MARS

Towards the end of last year, NASA's engineers on Earth commanded the Mars Curiosity rover to use its black-and-white cameras to take two photos of the scenery: the first at 8:30am and the second at 4:10pm Mars time.

The lighting conditions at different times of the Martian day highlighted unique features in the landscape, giving NASA's artists the information they needed to colour the image in. These features were then spliced together into a single image. The blue hues are from the morning light, whereas the orange tone illustrates the afternoon.

Curiosity isn't just sightseeing, however. The rover was sent to climb Mount Sharp, a 5km-tall mountain that it has been exploring since 2014, and this is the view back down. The whole area sits within the Gale Crater, a 154km-wide basin formed by an ancient impact – its rim stands at a dizzying 2,286m tall and is just visible on the horizon.

NASA/ESA

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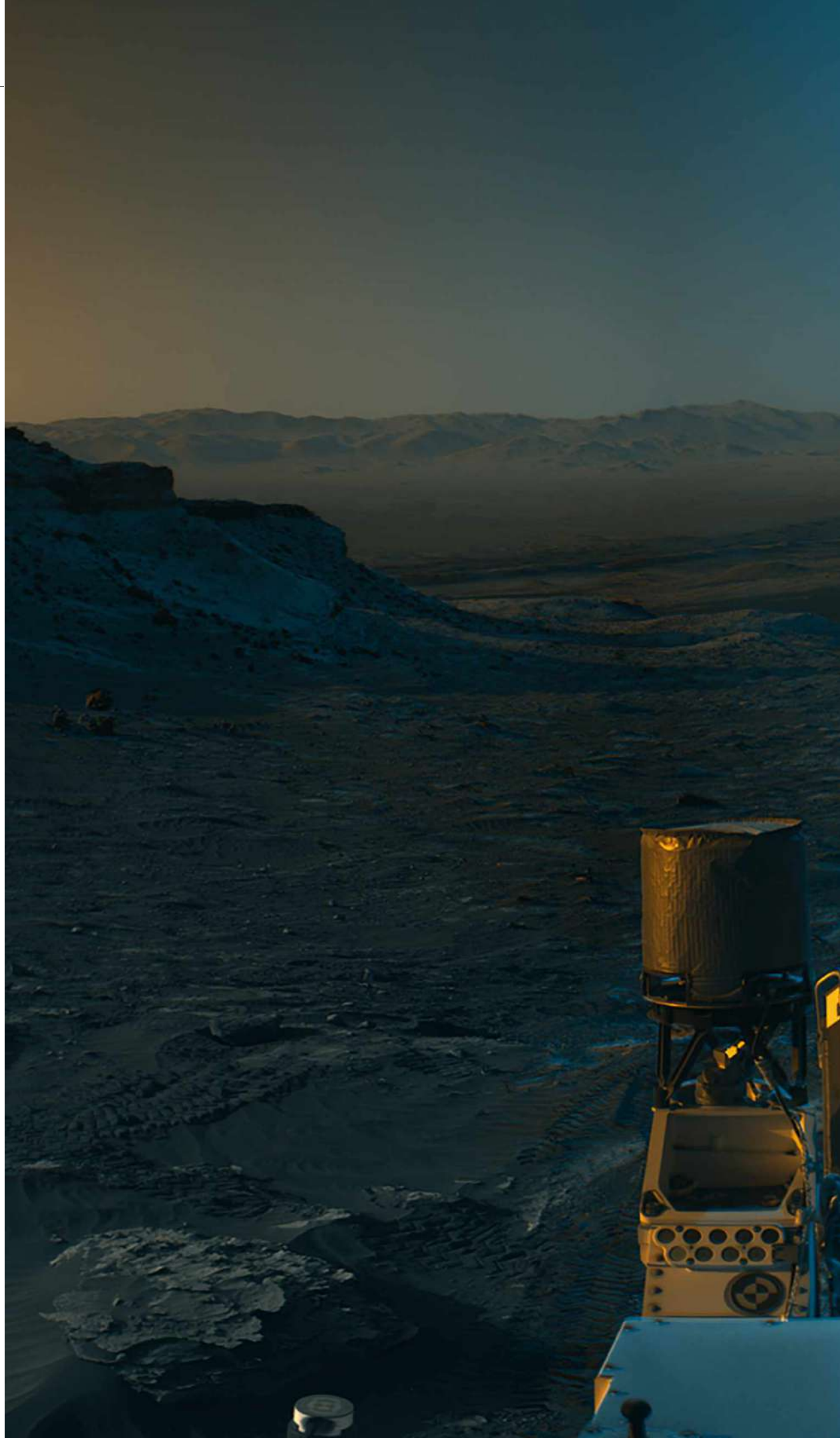

CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

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LETTER OF THE MONTH

Let's be smart

The augmented intelligence piece by Prof Peter Bentley (New Year, p72) focused on a very important issue – where are artificial intelligence and robotics heading towards, and what curbs and mechanisms should be put into place to control these technologies so that they don't get out of hand. From designing effective vaccines to managing the financial markets, both AI and robotics have improved our world so far. However, we must not rest on our laurels. We need these technologies to be regulated so that they don't fall into the wrong hands, thus causing untold damage. I strongly believe that science and technology are gifts, and they should be used for the betterment of humankind, not the destruction of life as we know it. An augmented approach led by good people where individuals are empowered by AI to make informed decisions about their own lives is a more intelligent approach than being led by technology and ultimately losing one's humanity forever.

Raheel Mughal, Birmingham

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a **JBL GO Work headset.** An affordable and feature-rich headset, GO Work is an ideal office accessory, allowing users to take calls online and via their phone without having to adjust Bluetooth settings. **uk.jbl.com**

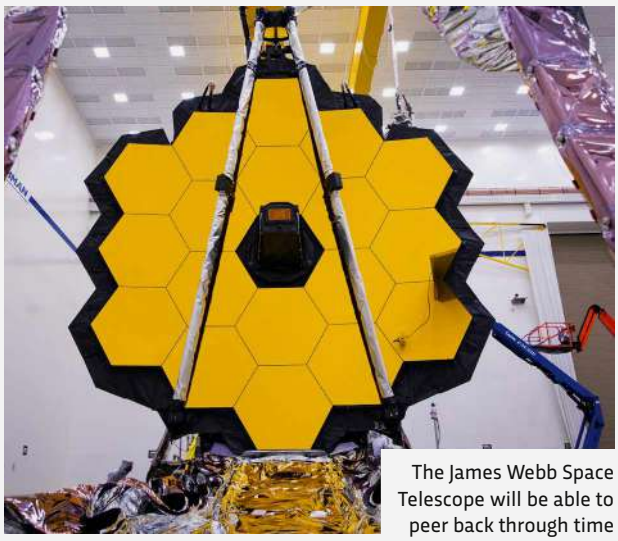
Time-travelling telescope

I note with much interest that the new James Webb Space Telescope will be powerful enough to be able to see far back in time to when the Universe was young (New Year, p25). I understand that the further away the object being observed is, the further back in time we see it because of the time the light takes to reach us. However, bearing in mind that nothing can travel faster than the speed of light, how did we get here before the image that the telescope sees?

Bob Rudman, Southampton

It's easy to imagine the Big Bang is like an explosion – all the stuff was in a small space, and then everything started to move rapidly outwards from there. But that's not the case: there isn't a spot in the Universe that was the centre of the explosion. The Big Bang happened everywhere at the same time. What this means is that we can see the early Universe by looking far enough in any direction.

That said, cosmologists believe that there was a period of faster-than-light expansion in the very early Universe, which explains



The James Webb Space Telescope will be able to peer back through time

"THE MOON IS LIKE A MUSEUM. WE SHOULD SCOUR ITS SURFACE FOR EQUIPMENT WE DID NOT SEND"

PROF AVI LOEB, P52

It doesn't matter how brave you are, a graveyard stroll on a cloudy night can still get your knees knocking

GETTY IMAGES X2, ALAMY

why the most distant galaxies look broadly the same when we look in opposite directions in the sky.
Sara Rigby, online staff writer

Can you scare the sceptic?

With regard to the letter from Jim Gardiner on the existence of ghosts (New Year, p21), it was the well-known polymath and sceptic, the late Isaac Asimov, who suggested (in one of his innumerable books) that even the most hardened sceptic might feel uncomfortable if they'd had to walk through a deserted graveyard at 3:30am with the wind whistling through the trees and clouds passing across the face of the Moon every few minutes.

Someone braver than myself might care to carry out the experiment and – hopefully – report back.
Peter Davey

Backwards time travel

BBC Science Focus keeps us in touch with great scientific advances, but I wonder if (backwards) time travel is really with us: your latest edition (372) is written as New Year 2021 below the barcode on the front cover. I am pleased to say that 2022 is the first year I personally have inserted the correct date in all my correspondence. I'd get out more but I'm too busy reading your excellent magazine. Happy New Year 2022!
Tim Williams, Heathfield

Well spotted, Tim! That issue of the magazine was sent to print on an extremely tight deadline where we were all exhausted and were fuelling ourselves on copious cups of tea and Christmas snacks. Clearly, the barcode was covered up by a rogue chocolate coin when we were checking pre-print proofs...
Alice Lipscombe-Southwell, managing editor

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ADVERTISEMENT FEATURE

AN IMPORTANT MESSAGE FROM PROFESSOR NICK LEMOINE CBE MD PHD FMEDSCI, CHAIR OF THE MEDICAL RESEARCH FOUNDATION

Gifts in Wills could be the key to protecting the future of human health

Our experience of COVID-19 shows how suddenly a global health challenge can appear. As someone interested in science, you will understand that while nobody can predict what we will face next, we can be certain that the future will bring many more threats to human health.

As Chair of the Medical Research Foundation – the charitable arm of the Medical Research Council – I have seen the incredible impact that individuals who remember the Foundation in their Wills can have on the future of our health and wellbeing here in the UK. These gifts fund research and researchers which can have far-reaching implications for human health.

With a gift in your Will you can play a key role in providing the science that will protect the health of future generations.

Right now, the Foundation is funding research to tackle antimicrobial resistance, and investing in researchers like Dr Myrsini Kaforou – who will make the fight against antimicrobial resistance her life's work.

Without support at the crucial early stages, researchers like Dr Kaforou can be forced to abandon their passion and leave science altogether, with an immeasurable loss to future human health. Gifts in Wills provide the long term funding and security that allows the Foundation to invest in projects like Dr Kaforou's and lay the foundations for quality research in years to come.

Your Will can fund the rational response to health challenges that medical science provides.

"As scientists, our duty is to secure the future of research for the generations that follow."

Professor Fiona Watt, Patron of the Medical Research Foundation and Director of the European Molecular Biology Organization.

While we don't know what the future holds for human health in the UK, we do know that research, and the brilliant scientists driving that research forward, are the key to meeting those challenges for years to come.

"The funding I received through the Medical Research Foundation will be transformative for my research." Dr Myrsini Kaforou

But many of these scientists rely on the generosity and foresight of fellow members of the medical community who understand the power of science and are willing to leave a gift to medical research in their Wills. At the Medical Research Foundation, over 90% of our voluntary income comes from individuals who choose to include a gift in their Will – they are crucial in the Foundation's ability to fund research that will enable the next generation of scientists to make real world discoveries in the future.

I firmly believe that a gift in your Will to the Medical Research Foundation is an excellent investment and will have a lasting impact on science and on the future of human health in the UK.

Please consider this very special gift today.

Professor Nick Lemoine CBE MD PhD FMedSci
Chair of the Medical Research Foundation

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DISCOVERIES

The Hunga Tonga-Hunga Ha'apai volcano spewed clouds of ash, gas and steam 20km into the sky

SHUTTERSTOCK

EARTH

THE VOLCANO THAT SHOOK THE EARTH

The eruption of the Hunga Tonga-Hunga Ha'apai volcano was a once-in-a-century geological event – and now the clock is ticking to study its effects...

The eruption of the submarine Hunga Tonga-Hunga Ha'apai volcano on 15 January 2022 left thousands of people without homes, supplies and internet. At the time of writing, there have been three confirmed deaths related to the eruption, two of which were locals, and one British national.

The volcano's explosion sent shock waves as far as Alaska and the UK, and caused a tsunami that affected the shores of Australia, the US and Russia.

Around 10 hours after the eruption, people in Miami in the US – more than 11,000km away from the volcano – saw pressure 'waves' at speeds of 1,100km/h. These acoustic ripples in the air were essentially ➔

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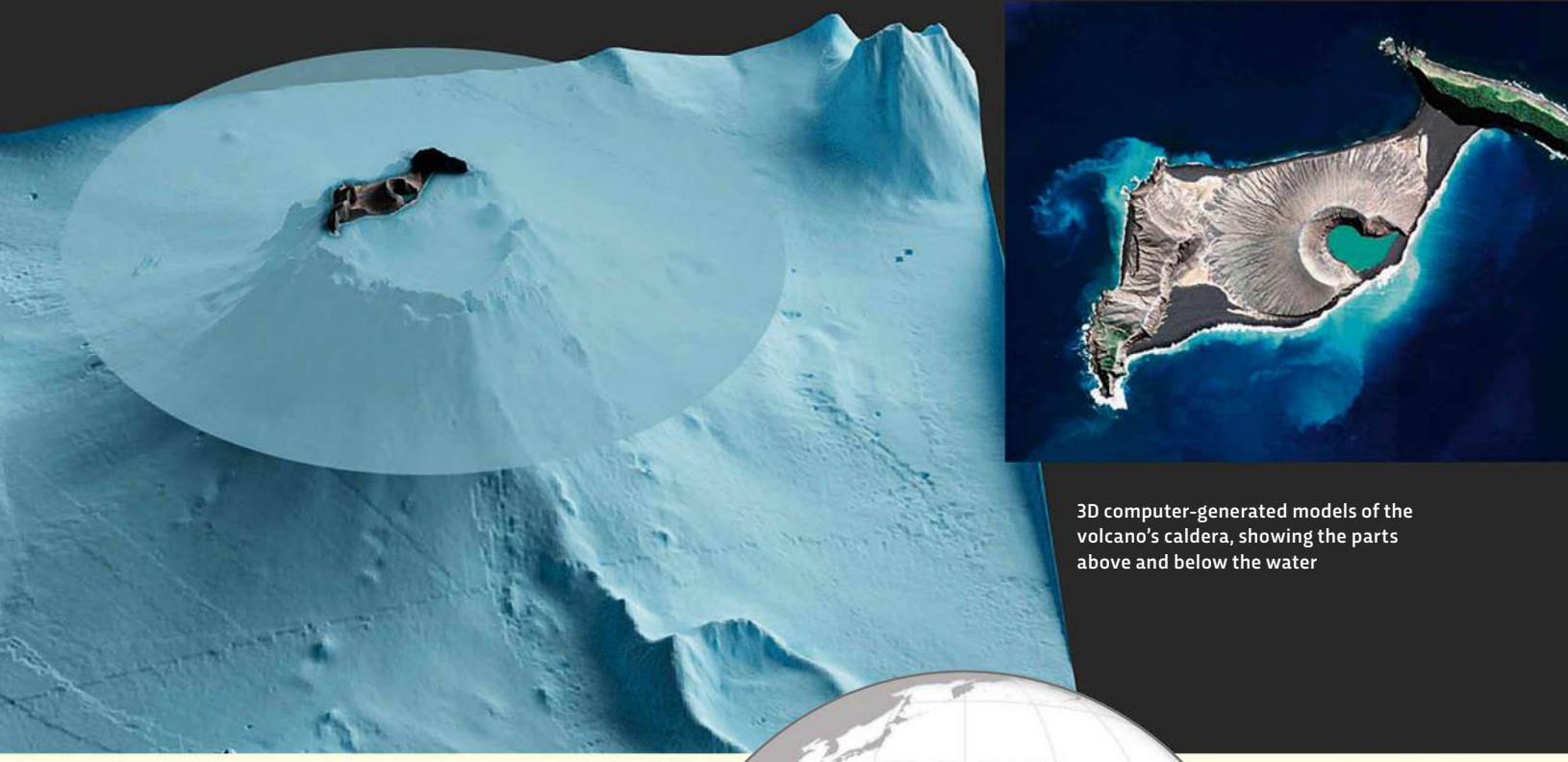
Be prepared NASA's tiny NEA Scout spacecra is set to explore an asteroid p24 **Water bears in space** Where will they go? p26



3D computer-generated models of the volcano's caldera, showing the parts above and below the water

travelling at the speed of sound through the atmosphere.

Five days after the eruption, the volcano's activity appeared to have stopped at surface level, although volcanologists could not say what was happening under the water.

Scientists still don't know why the Hunga Tonga-Hunga Ha'apai volcano erupted, but as it is a submarine volcano, it's likely to have been an sudden reaction, not something that had been bubbling under the surface for some time, said Dr Samuel Mitchell, a specialist in volcanic submarine systems at the University of Bristol.

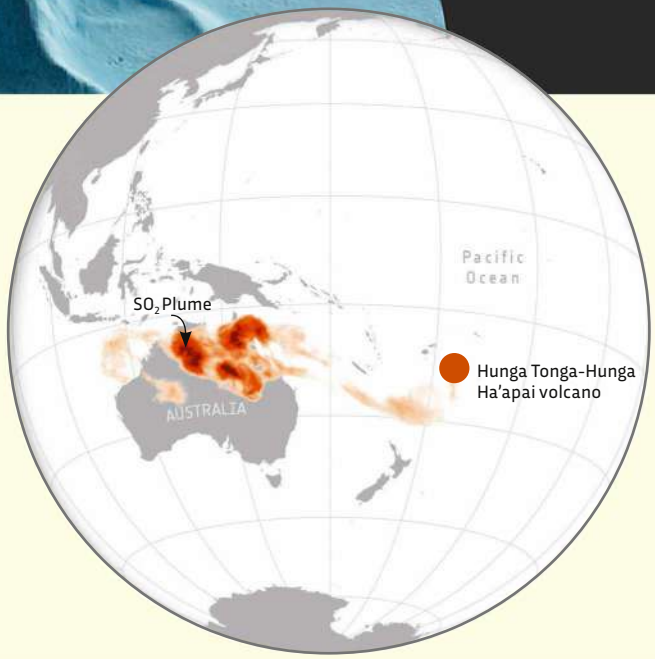
THE AFTERMATH

There are two uninhabited islands on the edge of the volcanic crater: Hunga-Tonga and Hunga-Ha'apai. Following the eruption, satellite images indicate these islands are a lot smaller, meaning the explosion likely destroyed a large part of the land. Scientists can't be sure whether the collapse of the crater caused the huge movement of water that created the tsunami, or if an explosion below the surface, propelling water away from the volcano, could have been the source.

As the tsunami spread, warnings were issued around the South Pacific and as far as Japan, Canada and the US. In Peru, the waves were so strong they overturned an oil tanker, causing more than 6,000 barrels of oil to spill out onto Peruvian beaches.

The extent of the eruption's effect on marine biodiversity is not yet known. However, Dr David Ferguson, a volcanologist at the University of Leeds, said that ash falling into the surrounding ocean will likely have the most significant impact.

"Ash erupted underwater doesn't tend to travel very far, however, the fact that the volcanic plume was ejected into the atmosphere allows the ash within it to be transported further and then deposited into the ocean nearby," he said. "If the amount of ash is significant, it can smother features such as coral reefs, and cause fish and other marine animals to move elsewhere, disrupting food chains, ecology, and more."



LEFT By 18 January, the sulphur dioxide (SO_2) plume from the eruption had reached across Australia

BELOW RIGHT In these images from before and after the eruption, you can see the effect of ash fallout in the town of Mu'a, Tongatapu island, Tonga

As the eruption occurred under the sea, it's likely that the resulting ash picked up salt from the water on its way to the surface. This salt may then have fallen over land, and some early reports suggest that the salt may be desiccating local crops.

WHAT WE KNOW SO FAR

Submarine volcanoes can be found around the globe at a variety of depths. But scientists don't yet know exactly how many there are. According to Mitchell, estimates suggest around 70 to 80 per cent of all volcanic activity actually happens on the seafloor. While these submerged volcanoes are relatively understudied, research from Hunga Tonga-Hunga Ha'apai will help volcanologists better understand and predict future events.

"There may now be an effort to study the consequences of the eruption, such as the effects on local marine life, and perhaps to monitor any post-eruptive changes or processes at the volcano itself," said Ferguson. "For example, it may be that magma is still in motion beneath the volcano and that the detection of this movement can help us understand the pathways that magma takes on its way to surface."

FREDERIK RUYS / VIZUALISM, SHUTTERSTOCK/EUROPEAN UNION COPERNICUS SATELLITE

“There is indirect evidence that there’s volcanic activity on Venus. Some infrared signals look like hot lava, but we can’t see details, just a hotspot”

BEYOND EARTH

The eruption could even help further our understanding of volcanoes on other planets. Previous eruptions by submarine volcanoes have resulted in the formation of islands, as the ridges of the volcano move and break the surface of the water.

“These islands formed of pyroclastic material have the same general morphology as features seen on Mars,” said Dr Ashley Davies, a NASA geologist and planetary scientist. “This suggests that the Martian features may have formed under similar circumstances – initially highly explosive events due to magma interacting directly with water.”

On Earth, these volcanic islands usually erode rapidly after formation. But if the features on Mars formed as a result of the same volcanic processes, then the persistence of these ancient features suggests fewer erosional forces are at play, allowing them to persist for billions of years. Scientists can’t say for sure if or when Mars’s volcanoes erupted, nor what these eruptions would’ve been like. However, we do know that in the distant past there was water on Mars.

“Mars had water on the surface in the past, and has ice just below the surface now, which gives potential for those kind of [lava and water] interactions,” said volcanologist Prof Lionel Wilson, from Lancaster University.

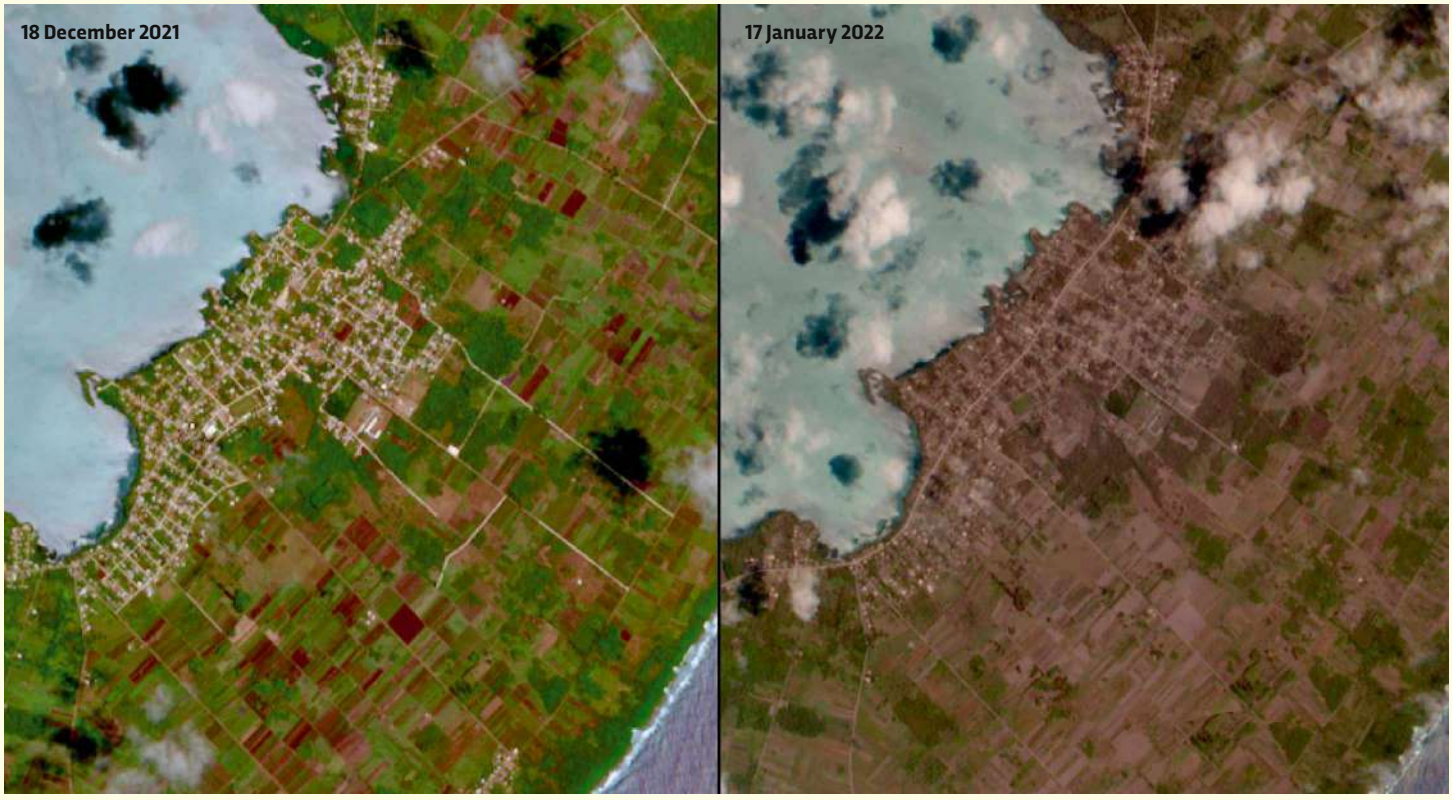
These days, Mars’s thin atmosphere means any water that comes to the surface just boils off. But around three billion years ago, atmospheric pressure could have been high enough to have standing water.

Some of the bigger volcanoes on Mars, like Olympus Mons and Ascraeus Mons, could be billions of years old. So, if there was an overlap between denser atmosphere and volcanic activity, explosions like that of the Hunga Tonga-Hunga Ha’apai volcano could’ve occurred.

“Tonga is at quite a shallow depth below the surface of the water, which is what made it so explosive. Deeper underwater, the high pressure tends to suppress violent interactions,” said Wilson.

While Mars’s volcanoes could have been active in a similarly low-pressure environment, volcanoes on Venus would erupt more like a deeper submarine volcano here on Earth.

“There is indirect evidence that there’s volcanic activity on Venus. Some infrared signals look like examples of hot lava, but we can’t see details, just a hotspot,” said Wilson. “But any gases dissolved in liquid lava on Venus would have a hard time getting out, so it’s not likely to be violent explosions. To get that classic fire fountain eruption, the gas needs the ability to produce bubbles that expand in the lava to tear it apart into little droplets.”



The surgeons place the genetically modified pig's heart into a storage device before its transplant into patient David Bennett

MEDICINE

Surgeons save terminal patient's life with a genetically modi ed pig's heart

This world-first operation proves that an animal heart can function just like a human heart, without the body rejecting it

A US man has become the first person in the world to receive a heart transplant from a genetically modified pig.

Surgeons say the experimental procedure was the only available option for the patient David Bennett, a 57-year-old from Maryland in the US, who was living with terminal heart disease.

Bennett is currently being carefully monitored while specialists at the University of Maryland Medical Center, where the procedure was carried out, determine whether the transplant can keep him alive in the long term.

"It was either die, or do this transplant. I want to live. I know it's a shot in the dark, but it's my last choice," said Bennett. "I look forward to getting out of bed after I recover."

The procedure required emergency authorisation from the US Food and Drug Administration (FDA), which was granted on New Year's Eve. It was given the green light under the compassionate use provision, which is used when an experimental medical product is the only option for a terminal patient.

While full heart transplants are more controversial, pig heart valves have been successfully used for replacements in humans for years.

"This was a breakthrough surgery and brings us one step closer to solving the organ shortage crisis. There are simply not enough donor human hearts available to meet the long list of potential recipients," said Bartley P Griffith, the heart surgeon who performed the operation.

"We are proceeding cautiously, but we are also optimistic that this first-in-the-world surgery will provide an important new option for patients in the future."

> **"This surgery brings us one step closer to solving the organ shortage crisis"**

The modified heart used in this transplant was provided by a regenerative medicine company called Revivicor. On the morning of the transplant, the surgical team placed the replacement heart into a perfusion device to keep the heart preserved.

In the donor pig, three genes that would have led to the rapid rejection of the pig's heart were knocked out. Six human genes responsible for immune acceptance of the pig heart were then inserted into the genome. Finally, one gene in the pig was removed to prevent excessive growth of the heart tissue once it had been implanted.

"This is truly a historic, monumental step forward. While we have long been at the forefront of research driving progress toward the promise of xenotransplantation as a viable solution to the organ crisis, many believed this breakthrough would be well into the future," said Bert W O'Malley, president and CEO of the University of Maryland Medical Center.

SPACE

Mystery of Jupiter's polar cyclones solved using ocean physics

NASA's Juno spacecraft has sent back the first evidence that the massive polar storms are driven by a similar process to those governing oceans on Earth

Jupiter's atmosphere is one of the most turbulent places in the Solar System, and thanks to the spacecraft Juno, we know that the poles are home to gigantic, persistent cyclones that rotate around areas of low pressure without dispersing.

However, the mystery of why Jupiter's cyclones have remained so stable has intrigued scientists since they were first observed in 2016. The number of cyclones has stayed the same over this time period: eight in the north pole and five at the south.

These large cyclones are up to 5,000km wide – wider than the continental United States – and each is associated with intermediate (around 500km to 1,600km wide) and smaller-scale vortices, around 100km wide.

Now, a new study published in the journal *Nature Physics* has provided evidence that these massive cyclones at Jupiter's poles are sustained by the same forces that power ocean vortices here on Earth.

Jupiter's cyclones are driven by a process called 'moist convection', just like vortices in Earth's oceans

UNIVERSITY OF MARYLAND SCHOOL OF MEDICINE, NASA/JPL-CALTECH/SWRI/MSSS

The hotter, less dense air from deep in the gas giant's atmosphere is more buoyant, and so rises, where it condenses to form clouds. Meanwhile, cooler and denser air flows downwards. On Jupiter, the rapidly rising air within these clouds acts as an energy source, driving energy transfer and feeding the large circumpolar and polar cyclones in a process called 'moist convection'. This is similar to how ocean vortices on Earth are driven by the movements of cooler and warmer water.

"When I saw the richness of the turbulence around the Jovian cyclones with all the filaments and smaller eddies, it reminded me of the turbulence you see in the ocean around eddies," said study lead author and physical oceanographer Lia Siegelman, a postdoctoral fellow at the Scripps Institution of Oceanography at the University of California San Diego (UCSD). "These are especially evident on high-resolution satellite images of plankton blooms for example."

By analysing an array of detailed infrared images sent back by Juno, Siegelman and her colleagues were able to confirm the widely held hypothesis that the cyclones in Jupiter's north polar region were formed through moist convection. They measured temperature, calculated wind speed and tracked cloud movement, and by comparing these measurements with cloud thickness data, they were able to map these massive storms.

Siegelman says that understanding Jupiter's energy system could help to highlight the energy routes at play on our own planet. "To be able to study a planet that is so far away and find physics that apply there is fascinating," she said. "It begs the question, do these processes also hold true for our own blue dot?"

The Juno spacecraft is currently scheduled to continue operations until 2025 and is expected to make several more flybys of Jupiter before then.

ZOOLOGY

Pandas' gut bacteria help them stay chubby on an all-bamboo diet

Changes in the bears' gut microbiome in the season when nutritious bamboo shoots are sprouting helps them to gain weight and store fat ahead of leaner times

When it comes to picky eating, giant pandas are up there with the best of them. Despite weighing upwards of 100kg, the charismatic black-and-white Asian bears exist almost solely on a diet of bamboo.

But how do they maintain their rotund figures by consuming a food source with so little nutritional value?

Researchers at the Chinese Academy of Sciences' Institute of Zoology think they have the answer: pandas' gut microbiomes shift during the season when nutritious bamboo shoots sprout, allowing them to pack on the pounds and compensate for the lack of nutrients in seasons when there are only bamboo leaves left to nibble on.

"This is the first time we established a causal relationship between a panda's gut microbiota and its phenotype [observable traits]," said study author Guangping Huang. "We've known these pandas have a different set of gut microbiota during the shoot-eating season for a long time, and it's very obvious that they are chubbier during this time of the year."

Pandas aren't the only animals to experience a seasonal shift in gut bacteria as a result of changes in food availability. Some species of monkey have different gut microbiota in summer when they get to snack on fresh leaves and fruits, compared with in winter when they have to make do with tree bark. The Hadza, a tribe of modern hunter-gatherers living in Tanzania, also experience changes in their guts depending on what they are eating throughout the year.

To make the discovery, the team studied a group of wild giant pandas living in the Qinling Mountains in central China. For the majority of the year the bears feed on nutritionally lacking bamboo leaves. But during late spring and early summer, they get to gorge on protein-rich bamboo shoots. During this time, the team found that they have significantly higher levels of *Clostridium butyricum* bacteria in their guts.

To investigate the effect of this change, the team transplanted faeces, and therefore bacteria, from the wild pandas during the two different seasons into mice. They then fed them a bamboo-based diet for three weeks. The mice gained significantly more weight and had more fat when transplanted with faeces from the shoot-eating season, despite consuming the same amount of food.

GETTY IMAGES, ALAMY

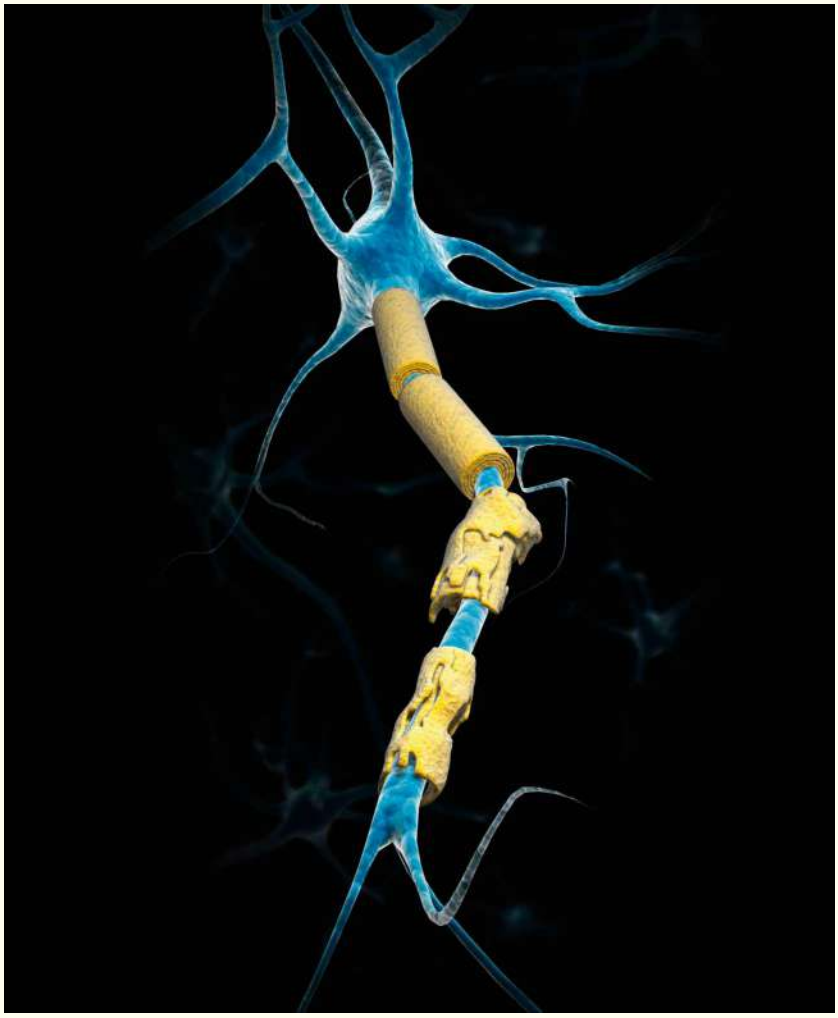
HEALTH

Malaria drug shows promise for hard-to-treat multiple sclerosis

Hydroxychloroquine, which is also used to treat rheumatoid arthritis, delayed the progression of disability in some multiple sclerosis patients

The antimalarial drug hydroxychloroquine could be a promising treatment candidate for slowing the progression of a rare form of multiple sclerosis (MS). In a small trial, patients who received the drug were less likely to significantly worsen over a period of 18 months.

MS is a lifelong condition that affects the brain and spinal cord. It is an autoimmune disease, meaning the body is attacked by its own immune system. Patients with MS often experience problems with vision, balance and coordination, and walking can become difficult. The cause of MS is unknown, and there is no cure. For the most common type, there are treatments that can slow the progression of the disease.



BELOW In multiple sclerosis, the myelin sheath (yellow) over a nerve cell (blue) becomes damaged. This demyelination causes nerve signals to become blocked or delayed

However, 1 in 10 patients has a form called 'primary progressive MS'. Unlike the most common type, there are no periods of remission and instead the symptoms gradually worsen and accumulate over time.

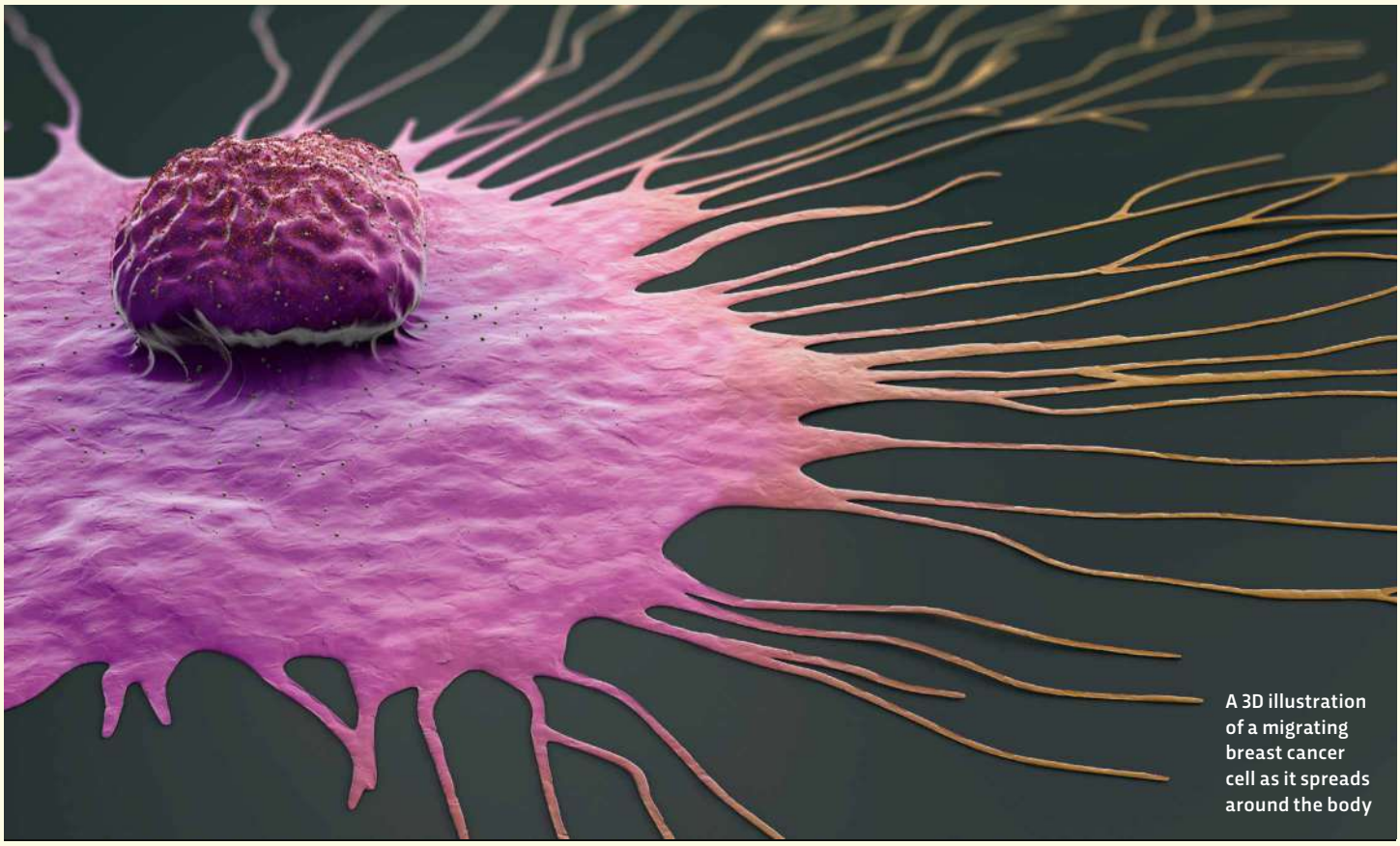
"With primary progressive MS, there is no good treatment to stop or reverse the progression of disease. The disability progressively worsens through time," said Dr Marcus Koch from the University of Calgary, who led the study with Dr Wee Yong.

> "Patients who received the drug were less likely to worsen over a period of 18 months"

"Dr Yong's research team, with whom we closely collaborate, has been screening a large number of generic drugs over several years and the results with hydroxychloroquine show some promise. Our trial is a preliminary success that needs further research. We hope sharing these results will help inspire that work, specifically larger scale clinical trials into the future," Koch added.

The researchers followed 35 patients over a period of 18 months between November 2016 and June 2018, and prescribed them two doses of hydroxychloroquine a day. After 6 and 18 months, they timed how long it took the patients to walk 7.6 metres (25 feet). They expected at least 14 of the patients to worsen significantly over the time, based on ongoing trial data, but in fact only eight did.

Hydroxychloroquine gained fame in 2020 as a potential treatment for COVID-19, with then-US President Donald Trump saying he took it to ward off the virus, despite warnings that doing so may be unsafe. A recent paper, which has not been peer-reviewed, found no evidence that the drug is an effective treatment for COVID-19.



A 3D illustration of a migrating breast cancer cell as it spreads around the body

HEALTH

New blood test can tell if cancer has spread around the body

The test could be performed at a GP practice and would help doctors prioritise patients with widespread and later stage cancer

Cancer researchers have developed a blood test that could improve diagnosis and treatment for patients. The test is the first to be able to detect not only the presence of cancer but also the spread of the disease around the body, which is often categorised in cancer stages.

Currently, patients diagnosed with cancer have to undergo imaging and testing so doctors can tell if it has spread to any other part of the body. A cancer that has spread is called metastatic cancer.

This knowledge then informs treatment, as patients with tumours in a single area are offered a local treatment, like surgery, while those with cancer that has spread would need whole-body treatments like chemotherapy or hormone therapy.

The new test, developed by researchers at the University of Oxford, uses a technique called NMR metabolomics, which identifies the presence of biomarkers in the blood, called metabolites. These are small chemicals that our body naturally produces. Metastatic cancer was successfully identified in 94 per cent of the 300 patients sampled.

"Metabolites are any small molecules in blood such as glucose, lactic acid, or amino acids," explained oncologist Dr James Larkin, who worked on the study. "The exact pattern of metabolites present in your blood varies depending on what is going on in your body, something which is influenced by diseases like cancer."

Crucially, if a person's cancer has spread, they will have a certain metabolomic profile that is different from a patient with localised cancer, or from someone without cancer.

NMR metabolomics technology could open up a wide range of new avenues for disease detection, not just in cancer but in other conditions too, said Larkin.

"We are only now starting to understand how metabolites produced by tumours can be used as biomarkers to accurately detect cancer," he said.

The researchers say that their new test will help patients who have symptoms that aren't specific to cancer of a particular body part. Whereas some symptoms, like a lump, would cause a doctor to immediately test for cancer, there are others that may be missed or go undiagnosed for some time.

They hope that patients presenting these non-specific symptoms, such as fatigue or weight loss, could receive the cancer test as part of a routine blood test.

SPACE

Exoplanet shaped like a rugby ball spotted by Cheops telescope

The European Space Agency's (ESA) exoplanet-hunting satellite has caught a glimpse of a planet deformed by the strong tidal pull of its host star for the first time.

Named WASP-103b, the planet is located in the constellation of Hercules around 35 light-years from Earth and is about twice the size of Jupiter with 1.5 times its mass. The planet is so close to its host star WASP-103, which is about 200°C hotter and 1.7 times larger than the Sun, that it completes a full orbit in less than a day.

Astronomers suspected that such close proximity between the star and its planet would cause a strong tidal pull, but up until now they haven't been able to measure it.

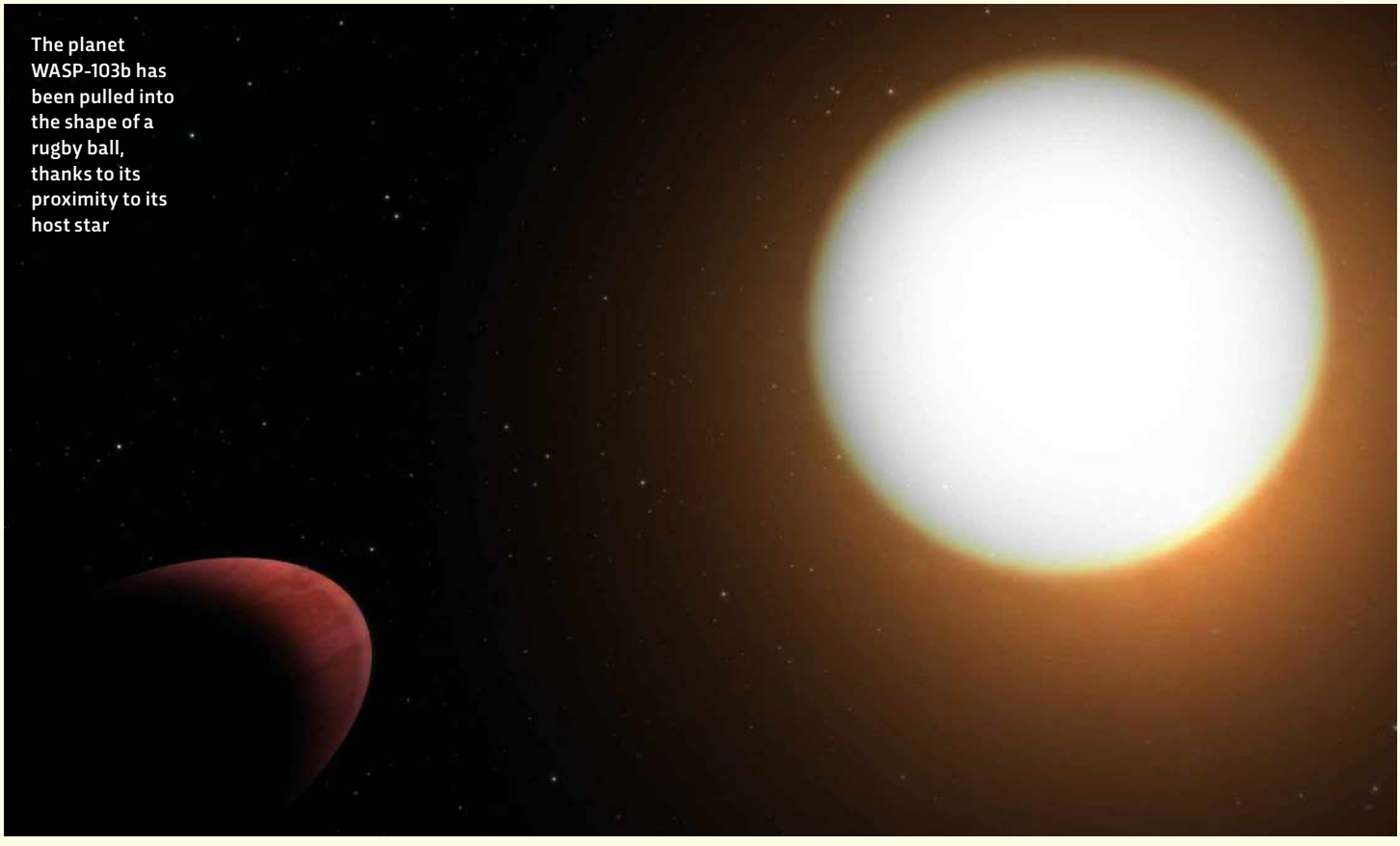
Cheops measures exoplanet transits – the dip in light caused when a planet passes in front of its star. Thanks to the high precision of the measurements the satellite took of WASP-103b over multiple transits, the researchers were able to determine that the gravitational pull of its host star is strong enough to stretch the planet into the shape of a rugby ball.

"The resistance of a material to being deformed depends on its composition," said lead author Susana Barros, of Instituto de Astrofísica e Ciências do Espaço and University of Porto, Portugal. "For example, here on Earth we have tides due to the Moon and the Sun but we can only see tides in the oceans. The rocky part doesn't move that much. By measuring how much the planet is deformed we can tell how much of it is rocky, gaseous or water."

The team was able to use the data collected by Cheops to determine WASP-103b's Love number – a measure of how mass is distributed within a planet. The Love number for WASP-103b is comparable to Jupiter, which suggests that the internal structure is similar, despite WASP-103b having twice the radius, the researchers say.

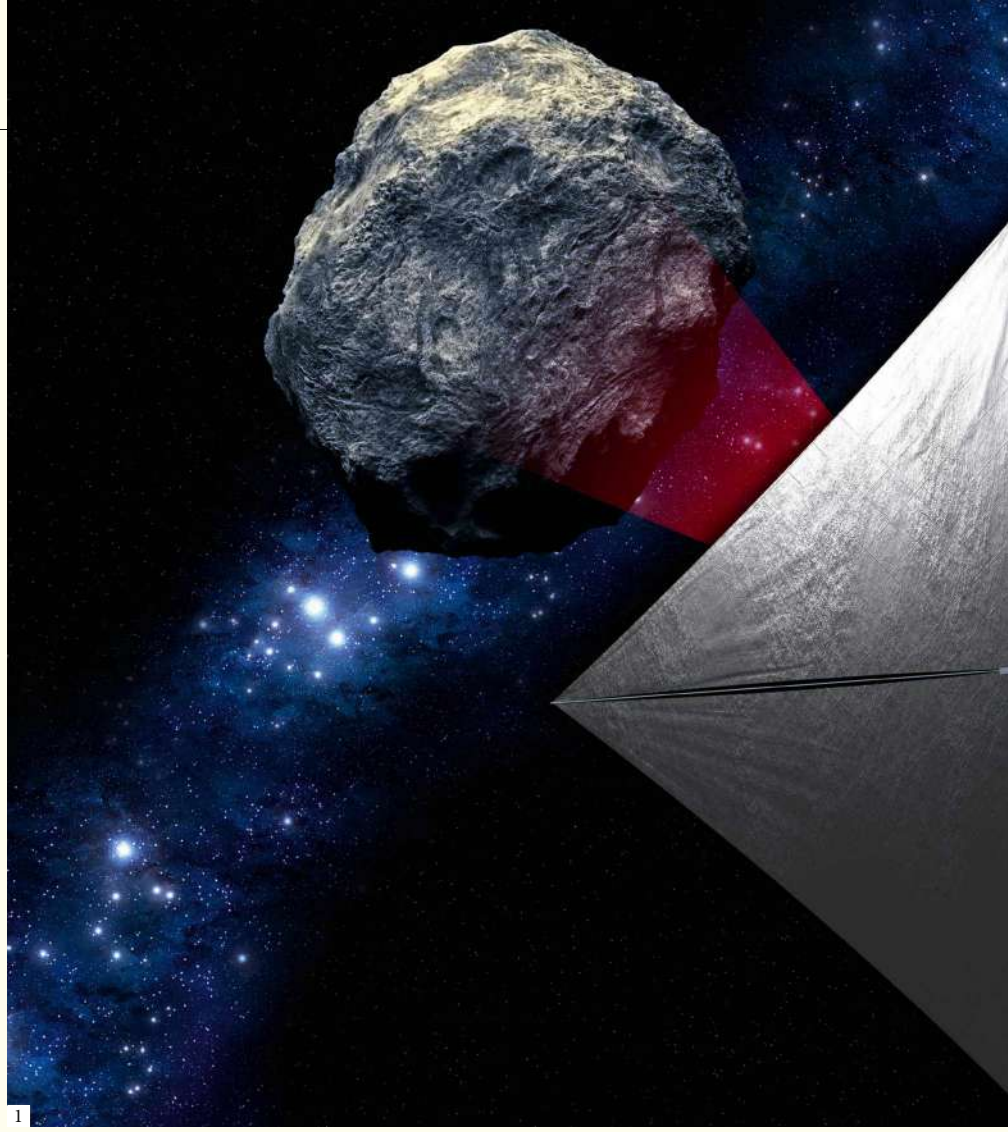
They now hope to study the planet further using observations from Cheops and the newly launched James Webb Space Telescope to shed further light on its internal structure.

"It's incredible that Cheops was actually able to reveal this tiny deformation," said Jacques Laskar of Paris Observatory, Université Paris Sciences et Lettres, and co-author of the research. "This is the first time such analysis has been made, and we can hope that observing over a longer time interval will strengthen this observation and lead to better knowledge of the planet's internal structure."



The planet WASP-103b has been pulled into the shape of a rugby ball, thanks to its proximity to its host star

GETTY IMAGES, ESA



1

SPACE

NASA preps a solar sail mission to chase down an asteroid

A space rock the size of a bus will be the target of this shoebox-sized spacecraft that will use the Sun as a means of propulsion.

Near-Earth Asteroid Scout (NEA Scout) will hitch a ride aboard the test launch of the Artemis rocket in March. Once in space, it'll deploy a solar sail which will reflect the Sun's radiation to propel it forwards.

Asteroids smaller than 100m across have never been studied up close. NEA Scout will pull up alongside its target and investigate its composition to work out whether it's a single boulder-like rock or if it's made up of clumps of dust and debris.

2

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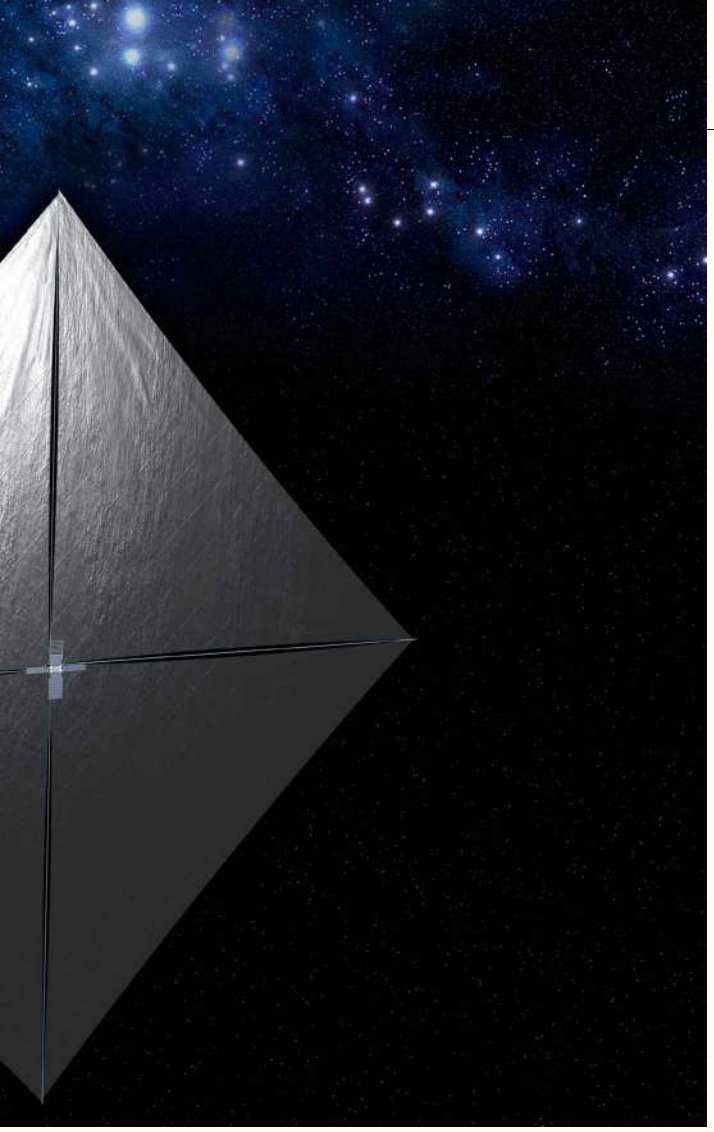
NASA X5



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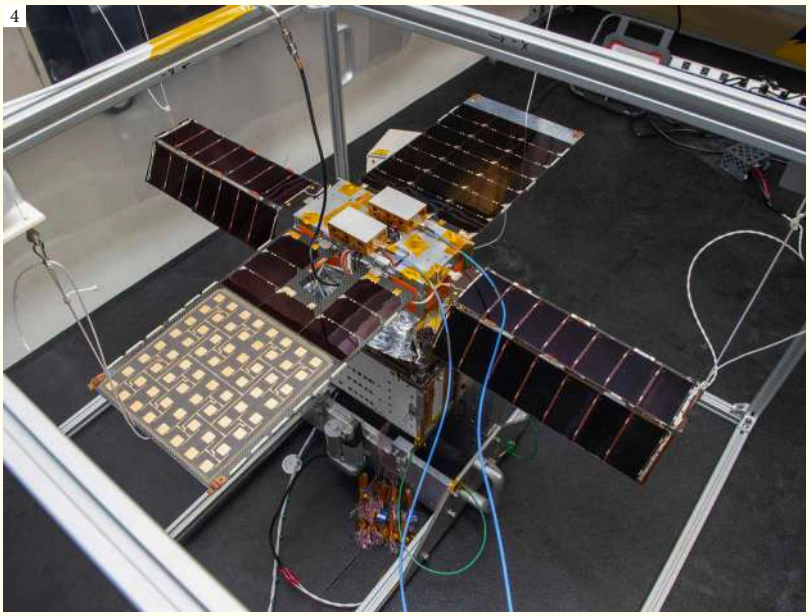

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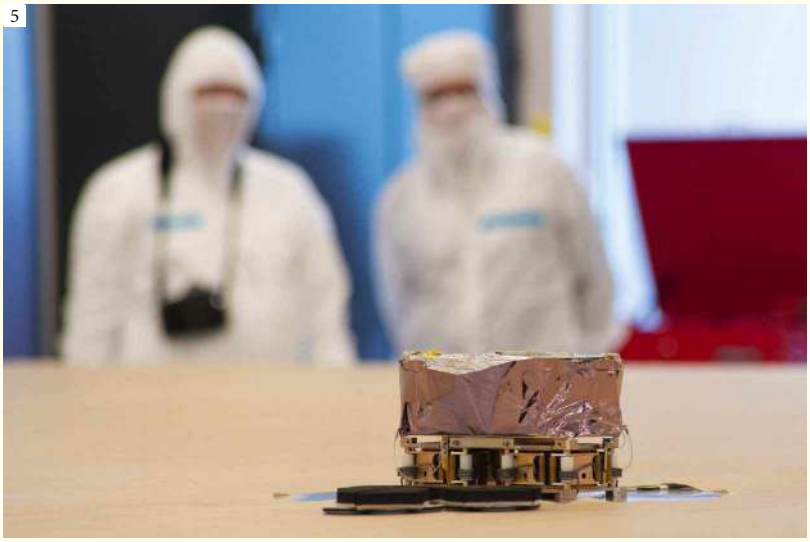

1. This artist's impression shows how the sail could deploy and take the payload to its target 2020 GE – a near-Earth asteroid that is less than 18 metres in size. Its journey is expected to take up to two years and will see the craft travel 150 million kilometres from Earth.

2. The craft's sail is made from plastic-coated aluminium that is thinner than a human hair. The propulsion is generated by the sail reflecting solar photons – particles of light radiating from the Sun. This solar sail technology allows vehicles to be propelled indefinitely through space and cover great distances.

3. Packed down into its CubeSat form factor, NEA Scout will hitchhike as one of 10 payloads aboard an Artemis Space Launch System rocket, scheduled to launch sometime in March 2022 from NASA's Kennedy Space Center in Florida.

4. This picture shows NEA Scout in its deployed state. Its camera has been specifically designed to accurately measure the size, shape, rotation and surface properties of the target asteroid. It will take images of the asteroid in resolutions ranging between 50cm pixels and 10cm pixels.

5. NEA Scout's sail was packed down to the size of a lunchbox to take up as little room as possible before launch and deployment. Once deployed, the sail will stretch out to become 86 square metres in area.

STEPHEN LANTIN
NASA space technology graduate researcher

Horizons

Microscopic water bears could be the first interstellar space travellers

A group of NASA-funded physicists, philosophers and biologists have come up with a list of organisms that could withstand interstellar space. Team member Stephen Lantin tells us more...

In 2019, a spacecraft containing strange, microscopic organisms crash-landed on the Moon. Israel's Beresheet Lunar Lander was the first non-governmental craft to attempt a landing on the lunar surface. It carried a collection of items, including a digital copy of Wikipedia, human DNA samples, an Israeli flag, and thousands of tiny animals called tardigrades. We can't say for sure if any of the so-called 'water bears' survived the crash, but if they did, they are the only Earthlings to have spent years away from their home planet.

ISRAEL SENT TARDIGRADES TO THE MOON, AND NOW YOUR RESEARCH TEAM HAS DRAWN UP PLANS TO SEND MORE ORGANISMS INTO SPACE. HOW DID YOU CHOOSE WHAT TO SEND?

First, we decided the organisms needed to be small. The smaller they are, the more we can pack in. And if a couple of them die, at least we might have some that survive. That narrowed it down to things like tardigrades, certain forms of bacteria, single cells and also a worm called *Caenorhabditis elegans.* This worm is the model organism chosen for a lot of studies in science.

Then we asked, can they survive the space environment? Experiments on the International Space Station (ISS) have explored this idea, and there are quite a few organisms that can survive the radiation environment in space without a lot of shielding. In space, there is radiation from the Sun, which we refer to as solar cosmic radiation. And the farther you get out, there's also galactic cosmic radiation that comes from elsewhere.

The organisms we picked have mechanisms that can repair their DNA if it's damaged by radiation. There's also this really interesting thing called cryptobiosis, where these organisms can undergo a sort of hibernation, but on a more intense scale. Their metabolic activity just completely drops. It's almost like they're dead, but they're not, because once conditions are right they can revive themselves.

SO CONCENTRATING ON TARDIGRADES, CAN YOU TELL ME WHAT THEY ACTUALLY ARE?

They're pretty simple organisms. They're also known as water bears, because if you look at them microscopically they look like eight-legged bears. But what's really cool about them is their radiation tolerance. They have the ability to withstand very extreme environments. People tend to throw around the word 'extremophiles', but tardigrades are more 'extremo-tolerant' organisms.

You know, if you go outside and find some mossy rocks, take a sample and put it under a microscope, you'll probably find tardigrades.

HOW WOULD YOU HAVE CONTACT WITH THEM WHILE THEY'RE IN SPACE?

We'd have different sensors on board along with these organisms, so we can study their behaviour over time. Ideally, we would send them out in their dehydrated, cryptobiotic form, and then we would remotely wake them up, with some water or something. We would monitor them, to see how many of them actually revive in space. Then we'd look at how their cells change to see if there is a genetic response. By looking at the different cells, we can almost understand what's going on, even if we're really, really far away.

CAN THIS HELP INFORM US ABOUT WHAT WOULD HAPPEN TO HUMANS IN THE SAME SITUATION?

Yeah, absolutely. This, more than anything, would be testing how life responds to radiation environments that we ourselves haven't experienced. Testing these sorts of things will mean we can better characterise the response not just for small organisms, but for bigger ones as well.

Tardigrades, also known as water bears, can withstand extreme conditions, making them ideal candidates to visit outer space

GETTY IMAGES

"The organisms we picked can repair their DNA if it's damaged by radiation"

WOULD THEY RETURN TO EARTH?

Right now, we definitely don't envision them returning. They get accelerated to very high speeds [on take off], and in order to get them back, we would need to somehow accelerate them in the other direction.

DOESN'T THAT RISK THEM CONTAMINATING OTHER ECOSYSTEMS?

That is definitely where we get the most flack from people outside of that research. What about all the potential ecosystems that might have life on them? Are we ruining them by shooting out life into them?

The short answer is if the spacecraft are being launched at very high speeds, there's virtually no chance of them [the tardigrades] surviving an actual impact onto a planet. Anything that is launched that fast and hits any sort of target gets vaporised instantly. There's not really a way at this point to get them to colonise other planets.

We also consider how and what targets we choose when we're shooting these off into space. There's an ethical component to this research, which is why we brought on board our philosopher Michael Walthemathe. He is familiar with the ethics of doing these sorts of things. We had some very interesting conversations.

WHY CAN'T WE JUST SEND ROBOTS? WHAT'S THE BENEFIT TO SENDING ORGANISMS?

Robots are good to use – we can use robotics to study exoplanets and learn lots of really good information. But it's not really an either/or situation. You can probably do both.

In terms of sending biology, this is something that we really have no experience with. We've never really done this before, in terms of sending organisms that far into space. The only stuff we've tested is in low-Earth orbit and the Moon. There are some plans to do research outside of low-Earth orbit, there's a biosensing programme at NASA's Ames Air Base in California. But largely, this space is untapped.

We thought it would be a good opportunity to push this out into the world, and see what people thought.

WHEN COULD TARDIGRADES BE SENT INTO SPACE?

We worked with a NASA-funded programme called Project Starlight, and its method for sending spacecraft into interstellar space could be ready in, as a rough estimate, 20 years, but that doesn't mean they'll be onboard a 2040 flight.

Project Starlight's whole big thing is laser sail propulsion: shooting lasers, either from the ground or from a separate spacecraft, and directing them onto a sail.

YOU MEAN, LIKE THE WIND SAIL ON A BOAT?

Exactly. Doing that imparts the momentum from the photons [particles of light] in the laser into the sail, which launches something at high speeds.

The propulsion physics have been tested. So we know that something like this would work. The only problem is scaling it up. We would need very large laser arrays – on the scale of kilometres – to accelerate things to significant fractions of the speed of light and send a craft like this into space.

That's not to say that large scientific projects like this haven't been done before. Look at CERN: they built a 17-kilometre ring to study particle acceleration. If there's the imperative to do something like this, we could. We have the energy to do it, there's a lot of good nuclear fusion research coming online. This is something that could be reasonably done.

However, no one's really working on the biological payloads for interstellar space quite yet. We hope with our paper that we can convince people to start thinking about these things.

STEPHEN LANTIN
Stephen is a PhD student and NASA space technology graduate researcher.

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REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Vegan fast food | Are we having less sex? | Postnatal depression in dads

REVIEW

VEGAN FAST FOOD: ARE PLANT-BASED ALTERNATIVES GOOD FOR YOUR HEALTH?

From sausage rolls to chicken nuggets, plant-based junk food options are everywhere now. But are we really being kinder to our bodies and the planet if we switch to meat-free fast food?

"Picking the vegan option over beef when ordering a burger could shrink your meal's cost to the climate and the environment by up to 96 per cent"

BBC

Visit the BBC's Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

Social media influencers, food producers and fast food brands alike are clambering on top of one another to promote their latest plant-based offerings – the new, much cooler way to say vegan or vegetarian. These businesses haven't suddenly developed a conscience, there's money to be made. The ethical triple whopper of climate, health and animal welfare concerns is driving meat-eaters to abandon animal flesh in favour of plant-based alternatives.

According to a study carried out by the UK Data Service, the number of vegans in Great Britain quadrupled between 2014 and 2019. Similar shifts are afoot across the developed world: Berlin-based vegan supermarket chain Veganz says that plant-only eating doubled in continental Europe between 2016 and 2020, and a report compiled by research firm Global Data found that the number of vegans in the US rocketed up by 500 per cent over a similar period.

In response to a greater demand for vegetarian and vegan choices, modern 'fake meat' is more like real meat than ever, and there is a bewildering number of options for the plant-based junk food lover to fill their faces with. But how do these new, ultra-processed products stack up when it comes to impacts on health and climate?

WEIGHING UP THE PROBLEM

It's often said that the best thing most of us can do to help combat climate change is to stop eating meat, particularly red meat. A study carried out by researchers in Sweden in 2019 found that industrial meat production is the biggest cause of deforestation globally, and that 77 per cent of agricultural land is used solely for meat and dairy.

Animals reared for meat are also gobbling up food that would help eradicate world hunger. According to a report published by Greenpeace, 90 per cent of soybeans grown are fed to the animals we eat. And the methane given off by cows is particularly good at helping to melt the ice caps, having 28 times the warming effect of carbon dioxide.

With very few exceptions, swapping meat and dairy for plant-derived equivalents will slash your contribution to destroying the planet. Research carried out at Trinity College Dublin found that picking the vegan option over beef when ordering a burger could shrink your meal's cost to the climate and the environment by up to 96 per cent.

While our consciences may have been pricked by all the talk of methane-filled cow burps, research shows that concern over the coming climate catastrophe isn't enough for most people to give up their meat fix, however. Rather, it is the promise of better health that gives us the final nudge to pick the meatless menu option.

Health-wise, eating less meat really is a good idea. Food writer Michael Pollan famously summed up healthy eating as: "Eat food, not too much, mostly plants." This truism has been supported with science countless times, with high meat and dairy consumption linked to obesity, bowel cancer, type 2 diabetes, heart disease and even dementia.

The EAT-Lancet Commission on nutrition has shown that the healthiest diet for us and the planet is largely plant-based, but including small amounts of meat, fish and dairy. For much of our existence we have survived on mostly vegetables, leaves, fruits, seeds, nuts and insects, alongside a little meat and fish. Our digestive system and the trillions of microbes that call it home are evolved for processing lots of flora.

Modern plant-based fast foods have a taste and texture more akin to real meat than the veggie burgers and sausages of yesteryear

ALAMY, GETTY

Vegan fast food is better on ethical and environmental grounds, but isn't necessarily good for your diet

Vegan burgers fall outside this ideal: a congealed disc of refined pea protein, emulsifiers, oils and lab-made starches, pepped up with sugar, flavourings and a lot of salt is about as close to a vegetable as a space hopper is to a spaceship. Imitation meats are among the most highly processed foods to ever grace our tables, effectively neutralising many of the health benefits a veg-filled diet should bring.

Vegan 'meats' fall into the newly recognised category of 'ultra-processed' food, which has been linked to the same health perils of eating red meat and fried food. The fibrous skins and the crunchy pith of vegetables that our gut microbes love, is scraped away long before a lump of fake meat plops onto the production line.

All the refining, milling, heating, cooling and pressing of those ingredients effectively gives us partially digested food that slips down the gullet easily and makes little use of the seven and a half metres of intestine that's designed to process food.

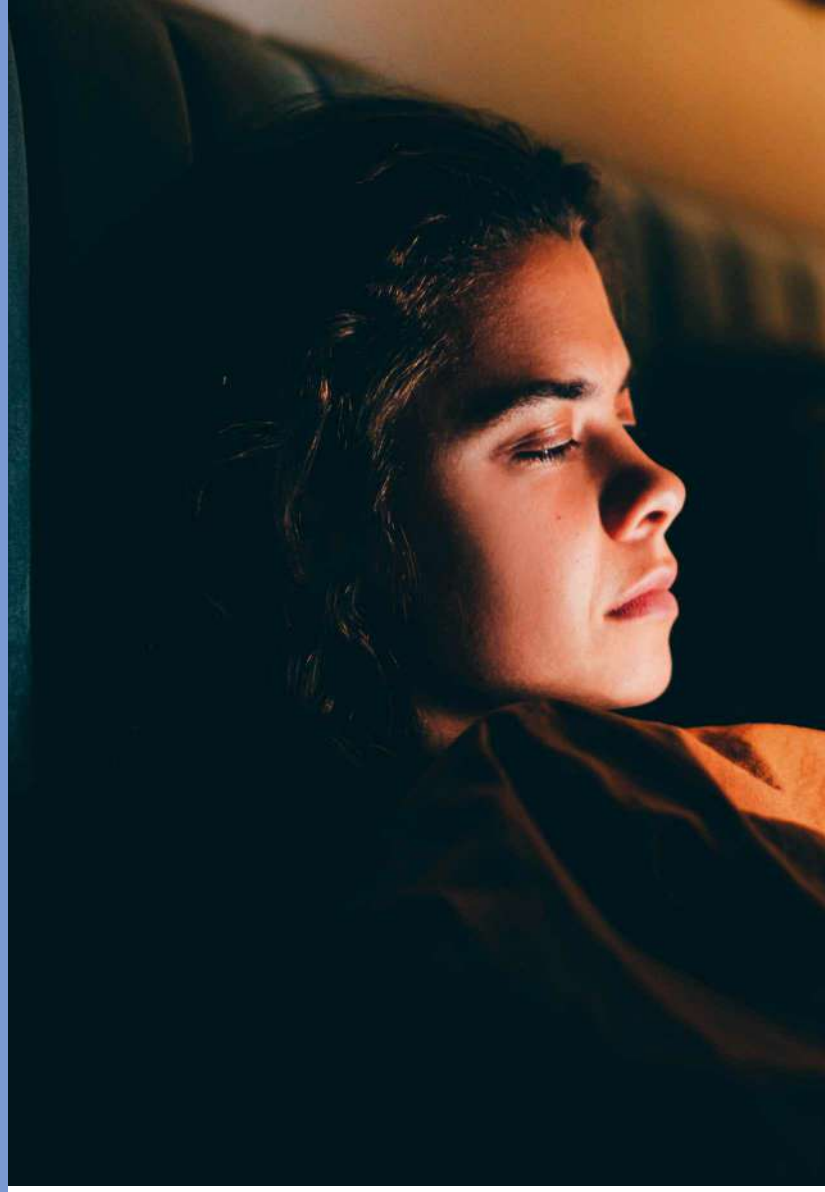
Sugars and fats rush into the bloodstream far quicker than our internal chemistry is equipped to handle; the healthy splurge of hunger-satisfying hormones, such as ghrelin, that follows a meal becomes a dribble, making us feel less satisfied and more likely to overeat.

But if you are a heavy junk food eater, then a plant-based alternative just might be the lesser of two evils. While generally being saltier, imitation meats do typically boast lower levels of saturated fat and higher levels of protein. In one small US study of 36 meat-eaters, swapping processed meat products for plant-based equivalents ended up reducing blood levels of harmful cholesterol as well as another blood marker of poor heart health.

But maybe the safest bet is to stick to another of Pollan's edicts: "Don't eat anything with more than five ingredients, or ingredients you can't pronounce."

by **DR STUART FARRIMOND**

Stuart is a food and health writer and presenter. His latest book is The Science Of Living *(£15.99, DK).*



ANALYSIS

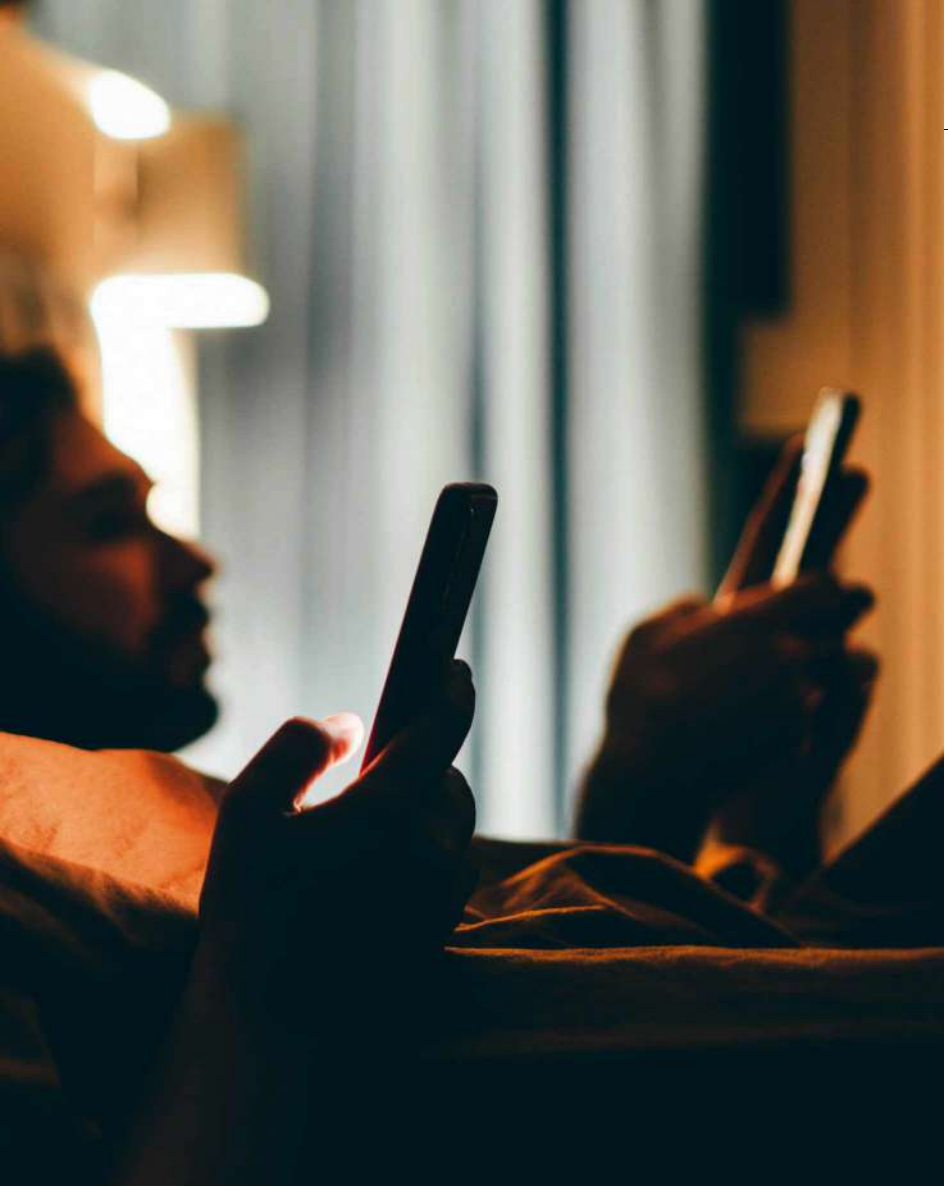
LOVE AND INTIMACY: ARE WE HAVING LESS SEX?

Research suggests that adults and teenagers are having less sex now than 30 years ago. But is there more to the story, and why does it matter anyway?

Adults and young people in the US seem to be having less sex than previous generations, according to a study published in November 2021. As is often the case, mobile phones have been named as the cause of this change in behaviour, but is that really what's going on?

The study was based on data from the National Survey of Sexual Health and Behavior (NSSHB), comparing over 8,500 individuals' responses from 2009 and 2018.

The results echoed a similar study in the UK, called the National Surveys of Sexual Attitudes



GETTY IMAGES, SHUTTERSTOCK

ABOVE Social media is often blamed for people not having sex, but this isn't necessarily true

and Lifestyles (Natsal), which has been collecting information about the public's sexual experiences for over three decades. The Natsal researchers have found that with every survey, the average number of occasions of sex per week has decreased: in 1991 respondents said they had sex five times a month. In 2000, this was down to four times per month, and by 2012, the average number was three per month. Unfortunately, the fourth survey was postponed due to COVID-19, though the researchers hope to complete the study in 2022-23.

When asked if Brits are having less sex, Soazig Clifton, the academic director for Natsal at University College London, replied with "a resounding yes". But it's not just a trend in the UK and the US. "If you look around the world, other comparable studies show a decrease as well. So, it seems to be a real international trend."

Studies in Germany looking at sexual activity in men and women showed a decline from 2005 to 2016, which the researchers suggest could be due to "a reduced proportion of [individuals] living with a partner". But Clifton says that after extracting the data of only cohabiting couples, they still found a decrease in sexual activity over the three studies.

"It's possible that people feel more comfortable talking about sex now, compared with the 1990s"

Both the UK Natsal study and the US NSSHB study split findings between adolescents and adults. Both found that the two groups were having less sex. For teens in particular, the US researchers found a significant difference in the instances of heterosexual sex – in 2009, 79 per cent of those between the ages of 14 and 17 said they had not had sex in the past year. Nearly a decade later, 89 per cent of adolescents reported no sex.

Some have asked whether this could be down to young adults' penchant (and perhaps preference) for social media and video gaming. Clifton warns that observational studies, like Natsal and NSSHB, "can't easily answer the 'why' questions".

"It is certainly theoretically plausible that people are spending so much time on their iPads and phones, connecting with others virtually rather than having sex with the person next to them," says Clifton.

But it's also possible that people feel more comfortable talking about sex now, compared with the 1990s.

"Maybe people are more able to tell us that they're not having sex. There is some statistical work we've done that shows we have a bit less reporting bias in our data. These decreases in biases would go along with the increased, more nuanced public conversation about sex." However, Clifton explains this wouldn't solely account for such a striking trend.

The idea that we are too busy – with phones, games or life in general – has been the subject of smaller, qualitative work by the Natsal. "The researchers worked with middle-aged women," says Clifton. "And something that came up in that research was that women were too tired for sex. They had so much else going on in their life."

But if busyness is to blame for us having less sex, then what about during the COVID-19 lockdowns, when we all had more time?

"We looked at the first lockdown, which was particularly restrictive, and the impact on sex lives was really different for different groups of people."

The Natsal-COVID study showed that for people living with a partner, the frequency of sex was roughly the same as before the lockdown. "In fact, most people didn't report a change in their satisfaction with their sex lives. Some people say to me, 'everyone will be having more sex because they were locked in a house together'.

It's just not the case," says Clifton. "However, we were more likely to see a decline in frequency and satisfaction amongst people not living with partners, and amongst young people."

Satisfaction, not frequency, is key. Prior to the pandemic, Natsal researchers found that most people believed others were having more frequent sex than they were having themselves. This misalignment could cause dissatisfaction in itself.

But why does it even matter how much sex people are having?

"It's part of the picture of understanding society, along with other areas of health and behaviours in our population," says Clifton. "Sometimes [sexual activity] gets dismissed as being less important than other aspects of people's lives. For some people, it's a really important part of their life."

These studies are even more important in countries with related problems, like declining birth rates. "Some of the countries who have also seen the decline in sex are quite worried about their declining birth rate – understanding patterns of sexual behaviour and frequency of sex are an important part of that puzzle."

In the UK, Clifton says that there are those that would like to be having more sex, though most participants who reported having no sex in the past year said they were not dissatisfied with their sexual lives. For couples and the importance of sex for sustaining relationships, Clifton says there is some evidence it's quality, not quantity, that matters.

"We don't need to be worried about whether our relationship is going to fall apart [because of it]."

In fact, 25 per cent of men and women who are in a relationship reported that they do not share the same level of interest in sex as their partner. What we see in the media, Clifton says, is a misrepresentation of what's normal in terms of sex. Instead of making people feel bad about their sex lives, understanding averages can help us feel happier with what we've got, three times a month.

—

by **AMY BARRETT**

Amy the editorial assistant for BBC Science Focus *magazine.*

COMMENT

NEW DADS: DO THEY GET POSTNATAL DEPRESSION?

Nearly one in four new fathers suffers from anxiety and depression in the first year following their children's birth. Should we be doing more to help them?

For women and men alike, becoming a parent is considered one of the most joyful experiences in life. Yet this widespread expectation brings with it a degree of cultural pressure, especially for parents who struggle with problems such as anxiety and low mood before or after their children are born.

Indeed, a significant minority of mothers – about 20 per cent – experience depression in the months before and after their child is born (known as perinatal depression, in contrast to postnatal depression which is exclusively after the birth).

Thankfully, awareness of these maternal mental health challenges has increased in recent years. This is a good thing, because left untreated a mother's mental health problems aren't only detrimental to her but to her infant too.

However, less known and recognised, is that fathers too are at increased risk of depression and anxiety around the time their children are born, which can similarly have adverse consequences for their children and their partners.

Previous research had suggested that around 10 per cent of dads experience perinatal depression. Now a Canadian study of nearly 2,500 fathers has given an even clearer idea of the scale of the problem, by estimating for the first time the proportion of dads who experience both depression and anxiety around the time their children are born. Having both conditions at once, which is known as comorbidity, is a more serious and complex clinical situation, one that's both harder to treat and more likely to have adverse consequences for children and partners.

The team, led by Dr Cindy-Lee Dennis at the University of Toronto, found that nearly one in four fathers experienced both anxiety and depression at some point during their children's first year, dropping to one in eight beyond the first year. The researchers said these high rates "demonstrate the importance of screening and early intervention for both depression and anxiety in men during the postpartum period [the first weeks after birth]."

These figures might be surprising to some, especially as postnatal depression in women is often attributed in part to issues that aren't usually considered to

GETTY IMAGES, ALAMY

"The transition after the birth of child for fathers can be marked by discord between who they used to be and who they are becoming"

ABOVE New fathers can struggle with the emotional upheaval of parenting

affect fathers directly, such as a difficult pregnancy or hormonal changes.

However, there is emerging evidence that becoming a father is also associated with significant biological effects, with studies finding reductions in testosterone and even changes in the brains of new fathers. Moreover, many of the risk factors for male perinatal and postnatal depression and anxiety are social and psychological in nature.

The Canadian study looked into these and found that important risk factors for the fathers in their research included having a history of mental illness, lack of social support, poorer health, problems forming a healthy attachment to their children, and having relationship difficulties with their children's mother.

In short, despite the potential for untold joy and love, becoming a father is also a period of intense change and challenge. "The transition after the birth of a child for fathers can be marked by discord between who they used to be and who they are becoming," the researchers say.

For dads who feel alone, who have pre-existing psychological vulnerabilities and/or have problems in their relationship with the mother, it is little wonder that depression and anxiety can flare up.

Compounding the problem for many fathers are the wider cultural expectations that pregnancy, childbirth and the aftermath are primarily a challenge for women, and that men should be strong, silent and supportive (men are especially guilty of holding this attitude about other men).

Relatedly, many existing support services for expectant parents tend to be biased towards mothers. Consider a British study from a few years ago that involved in-depth interviews with 10 first-time fathers – they spoke about the feelings of separation and helplessness triggered by antenatal classes that were almost exclusively focused on mothers and mothering.

Prof Viren Swami is a psychologist who has written about his own postnatal depression. One of his proposals for what would help is for support services to facilitate greater dialogue between fathers, especially between first-time fathers and fathers of toddlers and older kids.

Other proposals include wider societal changes that recognise parenthood as a period of intense change for fathers as well as mothers, through working practices that offer more generous or flexible paternal leave, for example.

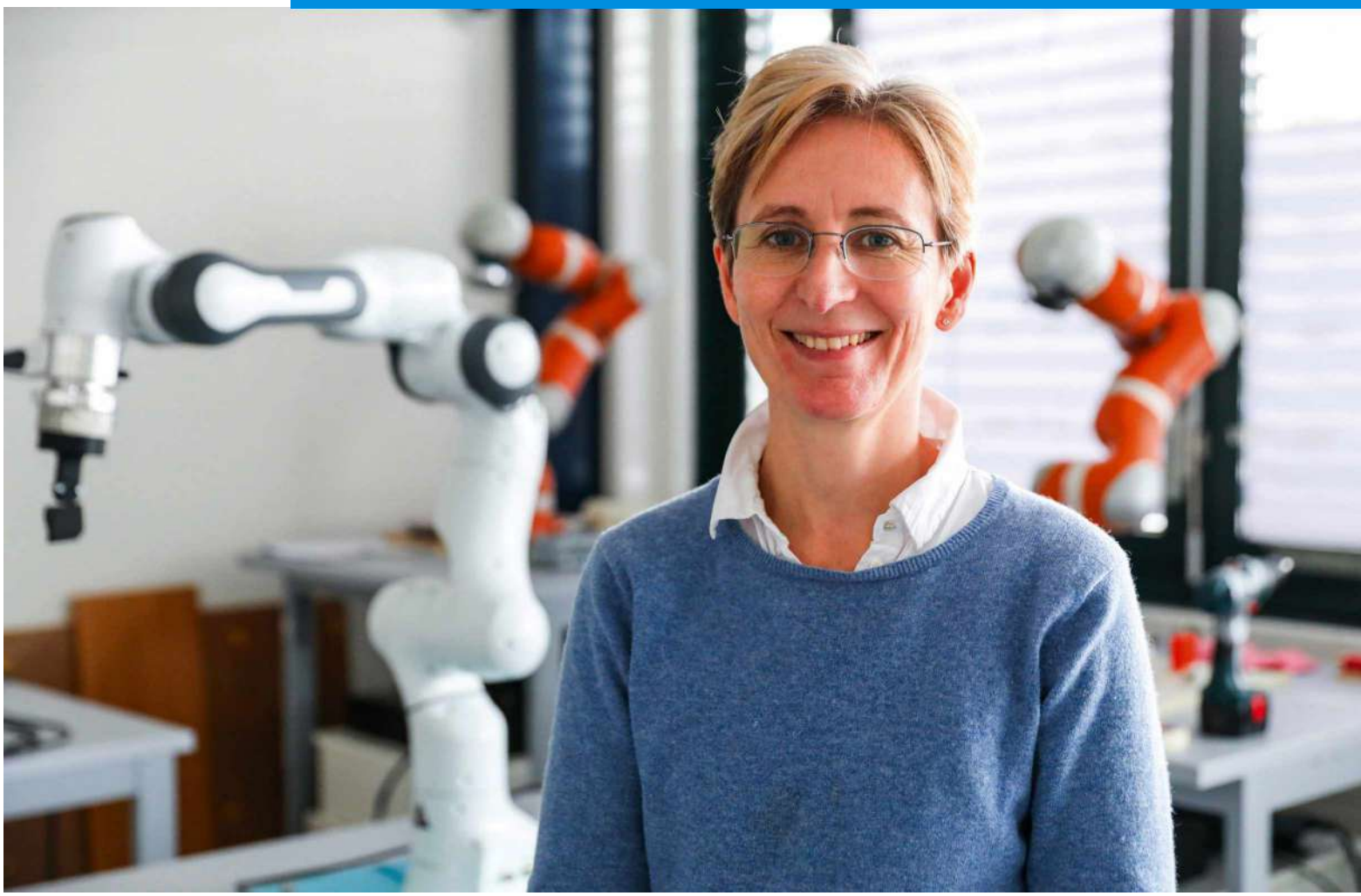
Of course, awareness of fathers' mental health challenges should not be at the cost of supporting mothers. In fact, all parents would benefit from advice on how to be mutually supportive of each other and on how to 'co-parent', which involves parenting collaboratively, making decisions together and dividing tasks fairly.

Thanks to campaign groups such as Fathers Reaching Out, awareness of the mental health challenges facing fathers does seem to be on the increase. In the UK, the National Childbirth Trust (NCT), which provides many educational classes for expectant and new parents, now has a webpage dedicated to postnatal depression in fathers, including advice on where to go for help. **SF**

by **DR CHRISTIAN JARRETT** *(@Psych_Writer)*
Christian is a psychologist, editor and author.

A swanky car that changes colour p40

INNOVATIONS PREPARE YOURSELF FOR TOMORROW



ROBOTICS

This robot arm can be controlled with your mind

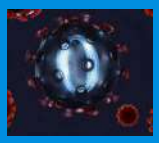
It's hoped the tech will one day help tetraplegic patients with day-to-day life

A robot arm, a machine-learning algorithm and a brain-computer interface have been combined to create a system to help tetraplegic (those who can't move their upper or lower body) patients interact with their world. While this isn't the first time a brain interface has been used to control a robot, it has taken the technology a step further by estimating and understanding brain signals without input from the patient.

The technology was built by two departments at the Swiss Federal Institute of Technology Lausanne (EPFL). One department was responsible for the algorithm that translated the brain waves into the signals the robotic arm could interpret, and the other built the brain-machine interface.

First, the user puts on an EEG cap, which effectively scans electrical activity in their head. These brain waves are then sent through a computer to be interpreted by the machine-

MORE ALGORITHMS



COVID PREDICTOR

Using blood samples, a German team of researchers have been able to predict which critically ill COVID-19 patients will recover from the virus. This is done using a machine learning tool that examines 14 protein levels in the patient's blood.

FISH LISTENER

Researchers using a machine learning algorithm were able to accurately identify 94 per cent of damselfish sounds. Fish sounds can help identify changes in the environment, temperature and other key issues in the water.

AMAZON SHOPPER

Amazon has recently unveiled plans for an upcoming clothing store. Along with a number of other smart features, the store will allow you to scan clothes that you like which will help a machine learning algorithm determine your style, pick items and recommend clothes.

The robot arm is controlled via the user's brain activity

The algorithm reads the user's brain for feedback on how the robot is moving

learning algorithm. The computer then sends signals to the robot arm to determine how it moves. As the robot arm performs a motion, the algorithm is reading the person's brain activity for signs of disapproval. The system is looking to get feedback, by mindreading, from the user when it makes a mistake: perhaps it moved too fast, or too aggressively.

The end goal is that the robot arm learns the right movements for a task in a given context. For example, you might want the arm to use a bit of force to throw a paper ball in the bin, but you might want it to be gentler when putting glass bottles in the recycling.

In the team's research, they trained the robot arm to pick up a glass. The arm would move towards the glass and the user's brain would decide if they felt it was too close or too far away. The process is repeated until the robot understands the optimal route for the individual's preference – not too close to be a risk, but not so far away to waste movement.

"PUTTING THE ALGORITHM INTO A WHEELCHAIR IS AN EXAMPLE OF WHERE THE TECH COULD GO IN THE FUTURE"

Training an algorithm to read brain waves in a consistent fashion was one of the main challenges of this research.

"The brain signals that we are recording will never be the same. We have a variability over time and this is natural. Why? Because if I move my hand, the brain is not only focused on that, the brain is processing many other things," said Dr José del R Millán, the head of EPFL's Brain-Machine Interface Laboratory at the time of the study. "So the fact that there is this variability means that our decoder will never be 100 per cent accurate."

However, through the machine-learning algorithm used in this research, the robot arm can gain a better understanding of variability to predict brain signals in certain situations. For example, the distance preference when moving past a glass.

Implementing the algorithm into a wheelchair is an example of where the technology could go in the future. This would allow people in wheelchairs to have greater control over their movements, speed and general safety. The algorithm could interpret brain signals to understand a user's speed preference, the distance they are happy to be from obstacles and people, and even the level of risk they are willing to take.

"It's interesting to use this algorithm instead of using speech, for instance, because there are things that you cannot necessarily easily articulate," said Prof Aude Billard, the head of EPFL's Learning Algorithms and Systems Laboratory. "A layperson may not be able to articulate that they don't like the acceleration of a wheelchair, for example. What is it that you don't like exactly? How does that translate into a control parameter afterwards?"

ALAIN HERZOG/EPFL X4, GETTY IMAGES, TIM CLARK/NATIONAL PARK SERVICE

INTERVIEW

The metaverse: will it be safe for use?

The next stage of the internet could be a Wild West if we're not careful. Alex Hughes spoke to Prof David Reid, an expert in AI, virtual reality and spatial computing, to find out more

The idea of a virtual world that we can interact with is rapidly becoming more likely. It's called the metaverse and it offers the potential of an internet that we will explore via virtual reality. But are the first users putting themselves at risk?

CAN YOU EXPLAIN WHAT THE METAVERSE IS?

There are a few definitions. You can think of it from a technological viewpoint, where it's simply the successor of the internet. Computers once took up big rooms, but they've shrunk until we got things like pocket-sized smartphones that you constantly interact with. The metaverse takes this a step further, making the actual environment you interact with virtual, removing the interface of computers completely.

Most people define the metaverse as an embodied internet. This means it allows you to interact and have visceral experiences in a surrounding that's almost like real life but isn't. The third common definition is where it's a tipping point. It's a moment in time where everything goes digital. Your friends, your job, your identity and your currencies.

HOW FAR OFF DO YOU THINK THE METAVERSE IS FROM OUR DAILY LIVES?

It's here. In the city of Seoul, they're investing about €3bn into creating a virtual Seoul cityscape. They'll be able to interact with people and create a virtual communications ecosystem where the municipal administration will take place. It'll include things like cultural interaction, tourism, education, civil services and more.

"ALL OF THE ISSUES OF THE INTERNET ARE ON THE METAVERSE, JUST MASSIVELY MAGNIFIED"

An event inside virtual world Decentraland

DECENTRALAND X2

Then there's Decentraland, which is creating real estate markets for the metaverse. The problem is that there are lots of different metaverses out there. Meta – previously Facebook – have theirs, Microsoft has their version and they're not really interactable. At the moment a lot of companies are building their own walled garden versions of the metaverse for their specific needs and niches. The metaverse will take off when you're able to interact between them.

FOR THOSE WHO AREN'T FAMILIAR WITH THE METAVERSE, WHAT DO YOU THINK THE RISKS ARE?

All of the issues of the internet are on the metaverse, just massively magnified. You could be interacting with avatars that look like people you know but it doesn't necessarily mean it's them. Social engineering to get passwords and money out of people all becomes a bit more realistic.

The metaverse is probably going to be funded on NFTs [non-fungible tokens]. This could attract the criminal fraternity as well who can launder money a lot easier or commit fraud, moving the contents to another part of the metaverse. These gangs could terrorise people, holding their avatars and their assets hostage, and those will have real value.

Viewing porn or being involved with violent acts and online bullying has a much more visceral and mental toll. All of those things, and protecting where kids can go, becomes far more difficult to police. In the metaverse, there are currently no rules.

ON THE INTERNET ITSELF, A LOT OF ISSUES GO UNCHECKED. HOW DO YOU SEE THE METAVERSE BEING POLICED?

Some restrictions have worked to a certain extent on the internet, but most haven't. Police forces are going to have to become far more involved with the type of technology used in the metaverse.

Organisations will need to get involved with the metaverse from the start to police it better than the internet was. There was little interest in policing crime on the internet at the start. If we're going to do it properly this time, we need to get in from ground zero to get big organisations involved.

If it ever becomes mainstream, it won't have any one person controlling it, like the World Wide Web doesn't have one person controlling it. What we need is something like the World Wide Web Consortium, which manages the standards for the World Wide Web.

PERSONALLY, WHAT ARE YOU MOST WORRIED ABOUT THE METAVERSE?

People get addicted to the internet but the metaverse will be even more seductive than the internet ever was. Spending days in the metaverse could become normal, so I can see metaverse addiction becoming a real thing very rapidly.

Decentraland is a 3D virtual world where you can buy and sell virtual plots of land

The potential for loss of biometric data and personal data is another big risk. The fact that if you move through a particular environment, you're giving lots of information away about who you are, what your preferences are and how you interact with people. There are people who could easily use this for nefarious purposes.

How can you protect young or vulnerable people who are susceptible to coercion or things they don't understand? It's a new and potentially hostile environment, but will there be any warnings?

The metaverse is shaping up a bit like the Wild West with no rules. Some of these factors could be thought of right from the start so we don't make the same mistakes as we did with the internet.

DO YOU REALLY THINK THAT PEOPLE WILL ADOPT THE METAVERSE, CONSIDERING ITS ISSUES?

I'm tremendously excited for the metaverse. It'll create new jobs that we haven't even considered yet. Nobody would have ever thought about the concept of an influencer when the internet first came around and now people are selling digital art, land and goods that don't exist in the real world.

The metaverse could transport a classroom to loads of remote locations. If you wanted to show somebody how the body or an engine works, that becomes far more nuanced. Through the use of haptic gloves, surgeons could practise lifelike surgery in the metaverse.

Virtual reality could really help a lot of older people too or those who are housebound, giving them the opportunity to mentally escape their environments. The key problem is that if people become too addicted to doing that, they could just prefer the virtual world.

PROF DAVID REID

David is a professor at Liverpool Hope University. He has worked with the internet since its earliest forms and now researches AI, augmented and virtual reality, and spatial computing.

Ideas we like...

↑ ...a tablet you can fold in half

Do you ever feel like your tablet just isn't flexible enough, that you should be able to bend it into a 75° angle? This is the incredibly niche problem that ASUS has attempted to fix with its Zenbook 17 Fold, offering a massive 17-inch OLED tablet that you can fold in half or bend to your chosen angle. In a market full of phones, tablets and computers that can fold, the Zenbook will have to pull out a lot of big features to really break through the noise.

ASUS Zenbook 17 Fold OLED
£TBC, asus.com

↑ ...a car that changes colour at the touch of a button

Want to feel like the new James Bond? BMW's iX Flow could get you some of the way there, without the murder, questionable politics and alcohol dependency. Unveiled at CES 2022, the iX Flow is a normal-looking car with one special feature – it can change colour. The car is covered in millions of microcapsules that contain negative and positive pigments of paint. Change the setting on an electrical field and the car instantly changes colour. Essentially, it's like a massive e-reader display has been stretched across the face of the car. Maybe not the most useful feature, but certainly a cool party trick.

BMW iX Flow
£TBC, bmw.com

...a speaker that only you can hear

The Noveto N1 has the potential to revolutionise the workplace if it works, or cause an office-wide feud if it doesn't. Noveto has created a speaker that directs sound straight to your ears without those around you hearing it, so you can banish your headphones for good. Noveto says that there is a 90 per cent reduction in audio when you're one metre away, while the user directly in front of the speaker still gets to enjoy maximum volume and clarity – an impressive claim. It also features Alexa voice control and face ID, so it can identify who is using it and adjust to their preferences.

Noveto N1
$800, noveto.com

←...a drone that flies itself

There are loads of drones out there and it takes a lot for a new product to stand out. Skydio's 2+ drone makes a splash with its Keyframe technology. This allows you to plan out a route for the drone to fly, choosing key spots for it to focus on. This takes the pilot out of the process, allowing you to concentrate on the filming. Once the route is programmed in, you can do it over and over again to your heart's content… without annoying a stressed drone operator.

Skydio 2+
$1,099, shop.skydio.com

↑...a smart projector for those on the move

Samsung has already unveiled a lot of new tech this year but a surprising entry was The Freestyle projector. The projector market is busy and although there are no wildly ambitious tools here, Samsung has managed to fit the features of large and expensive projectors into a small form factor with a relatively affordable price. It offers full HD quality, it is battery enabled so it can be taken on the move, it can scale to fit any size wall, it plays 360° sound and can even alter its image to offset a colourful wall. Smart.

Samsung The Freestyle
£999, samsung.com

↓...the next generation of scales

Want a pair of scales that will know every intimate detail about you better than your own family? That's what the Withings Body Scan can offer. This scale provides an extensive assessment of your body, measuring weight, muscle mass in your arms, legs and torso, your vascular age and nerve activity in your feet. This is measured through sensors in a handle that you lift up from the scale. These sensors send low voltage electric currents through the body, calculating the resistance of current as it passes through you.

Withings Body Scan
£TBC, withings.com

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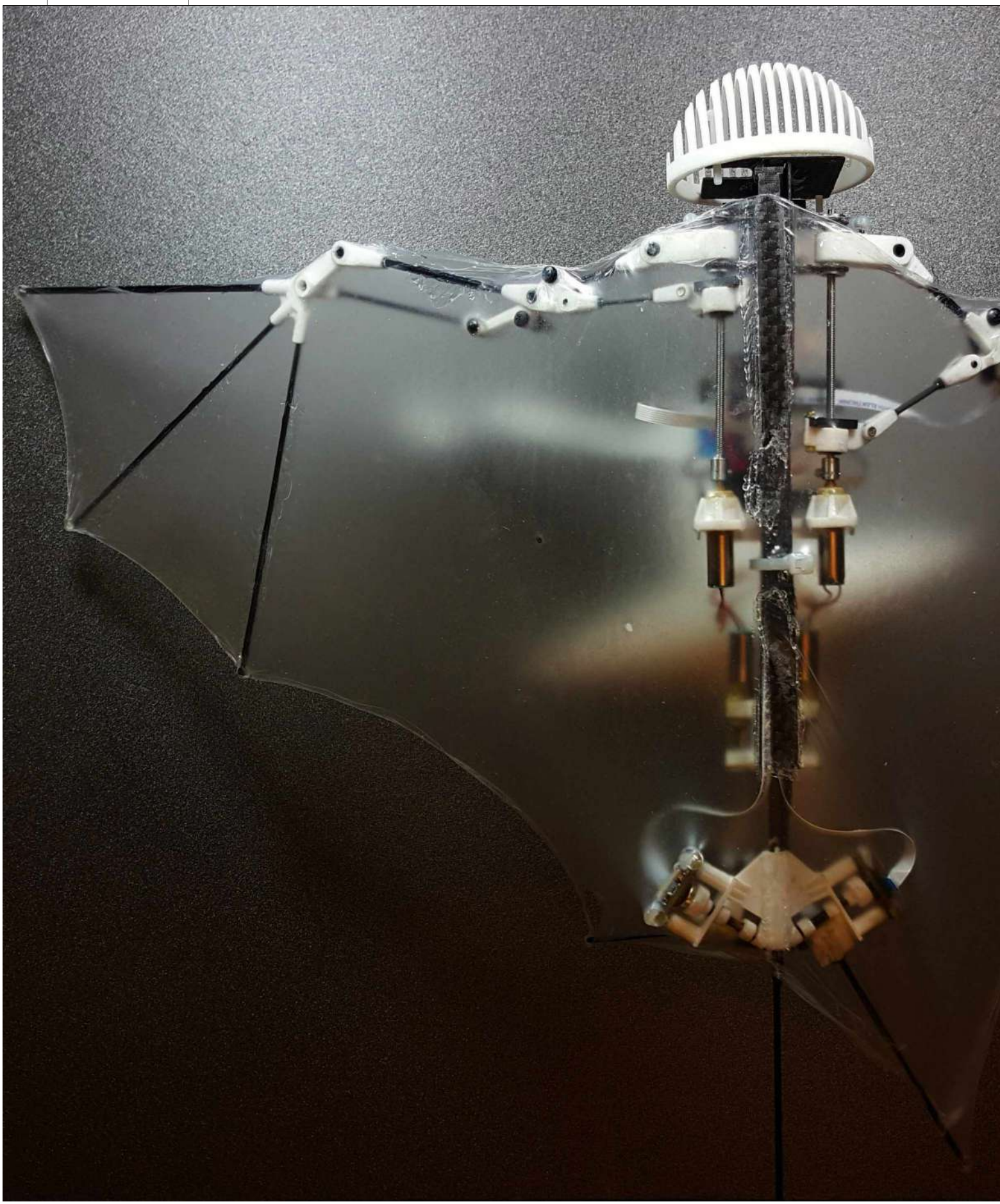

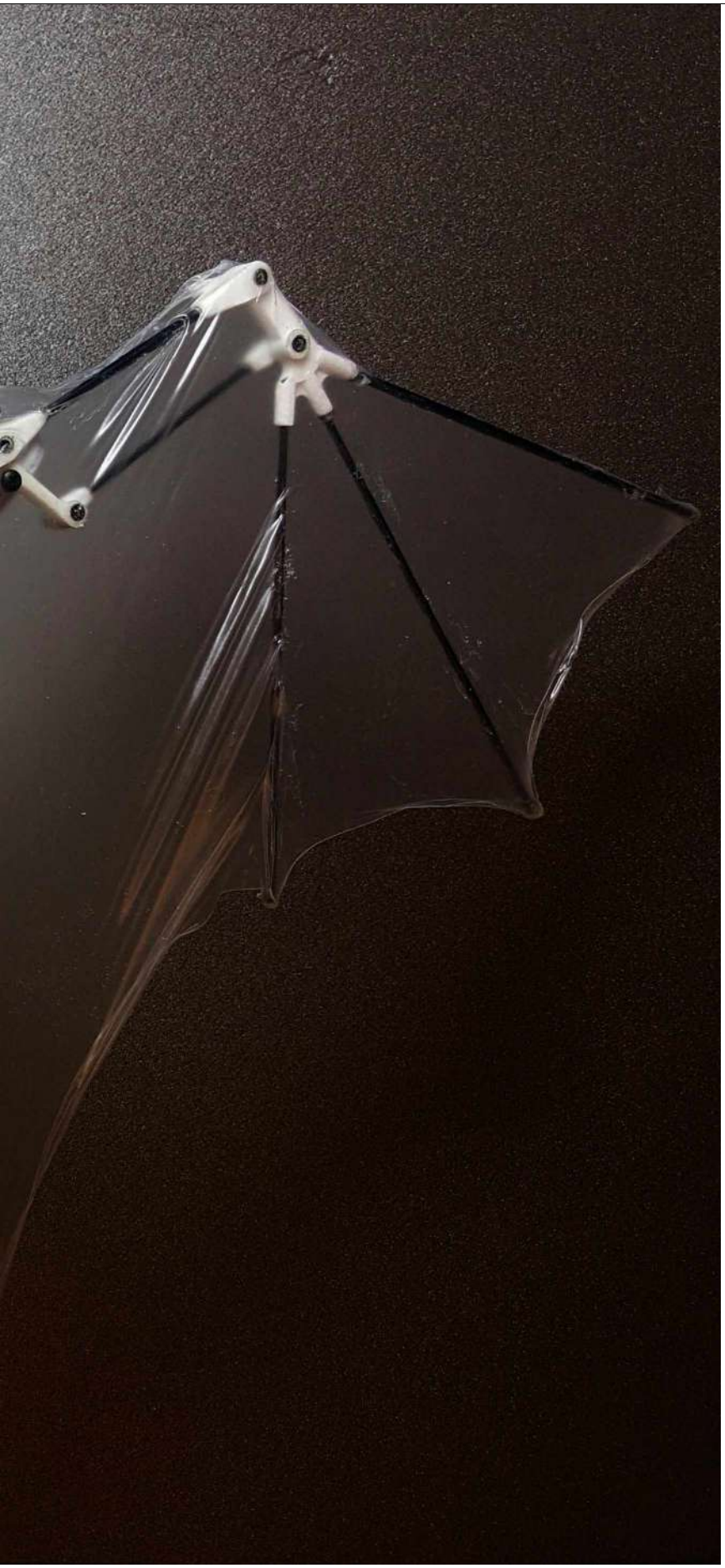

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THE BIO BOTS

BIO-INSPIRED ROBOTS THAT CAN FLY LIKE BIRDS AND CREEP LIKE COCKROACHES ARE HELPING RESEARCHERS TO UNDERSTAND MORE ABOUT HOW ANIMALS MOVE AND BEHAVE

WORDS: HAYLEY BENNETT

BAT KIT CRAZY

Bat flight is fiendishly complex, requiring a system of muscles, bones and joints that incorporate folding of the wings in every wingbeat. The force that bat wings generate comes from a strong but flexible covering of skin, as opposed to the rigid feathers used by birds. Basically, of all the flying beasts in the world, if you're going to pick one to try to emulate, don't pick a bat. Except that's exactly what US researchers did when they created this robotic bat, dubbed 'B2', to help them understand bat flight. In an article published in the journal *Science Robotics*, they explain how they stretched a 56-micrometre-thick (one micrometre = one-thousandth of a millimetre), silicone-based skin over B2's wings, enabling it "to morph its articulated structure in mid-air without losing an effective and smooth aerodynamic surface".

B2 can execute sharp diving manoeuvres and banking turns and, as well as providing a way to mimic and study the flight mechanisms of real bats, it may feed into the design of more agile flying robots of the future, helping us reach inaccessible places without sustaining damage or causing injury.

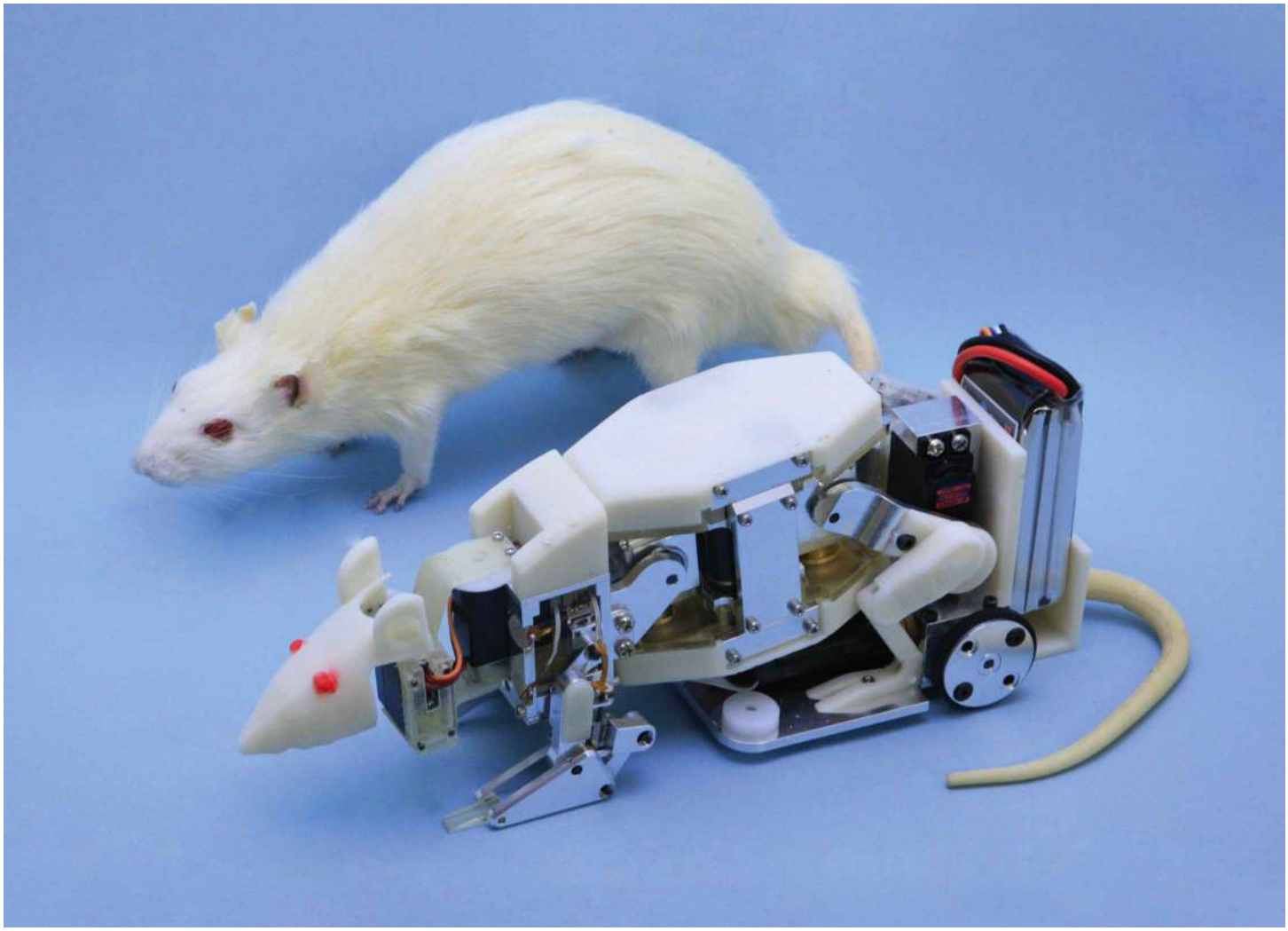
↑

GET A GRIP

The idea for this perching robot came from Stanford University engineer William Roderick, who was looking for a way to make a positive impact on the environment using his background in robotics. "It struck me as I was watching birds perching and flying through a forest [that] if there were a robot that could act like a bird, that would unlock completely new ways to study the environment," Roderick says.

Roderick and his colleague Prof Mark Cutkosky teamed up with Prof David Lentink at the University of Groningen to design aerial robots with bird-like claws that enable them to land on and grasp irregularly shaped branches. Similar robots could eventually be used in environmental monitoring, for instance, to raise the alert when there is a forest fire or to study wild animals. For now, just understanding and mimicking what birds do is proving quite a challenge. Perching requires strong legs and a good grasp, but also the branch needs to be approached at the right angle and speed to nail the landing. In a *Science Robotics* article published last year, the researchers described how they modelled their robot's legs on those of a peregrine falcon, incorporating motors to rotate the hips in the direction of the perch and artificial tendons that flex the toes and lock to grip.

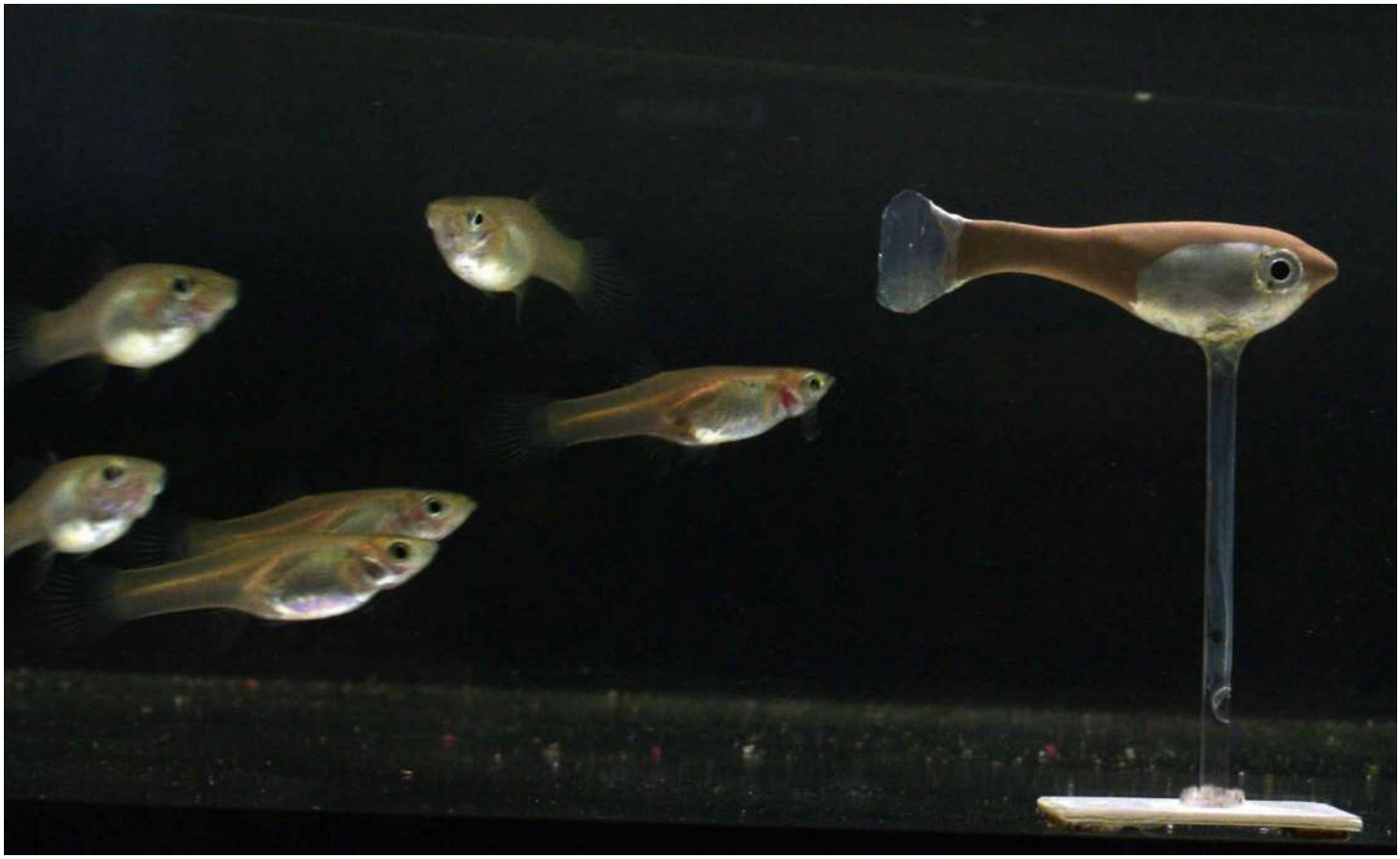
WILLIAM RODERICK X2, TAKANISHI LABORATORY/ISHII LABORATORY/WASEDA UNIVERSITY



"With further development, the WR-5 robotic rat could have a potential role in helping to pacify stressed lab rats"

ROBO RODENT

When scientists want to learn more about human mental disorders, they often look to animals with similar brains, such as rats and mice. These animals can act as important 'models' for human disease. However, the social impacts of mental disorders can be difficult to get a handle on in animals because of individual differences in the way they interact with others and in personality. So in an effort to help standardise these interactions, at least from one side, Chinese and Japanese researchers collaborated to produce the WR-5, a robotic rat that interacts with real rats to study social integration. While they say it needs to be able to perform more complex behaviours like grooming, WR-5 did have a noticeable impact on behaviour towards a 'target' rat, encouraging other rats to try to mate with the target. The researchers even suggest that with development it could have a potential role in helping to pacify stressed lab rats.



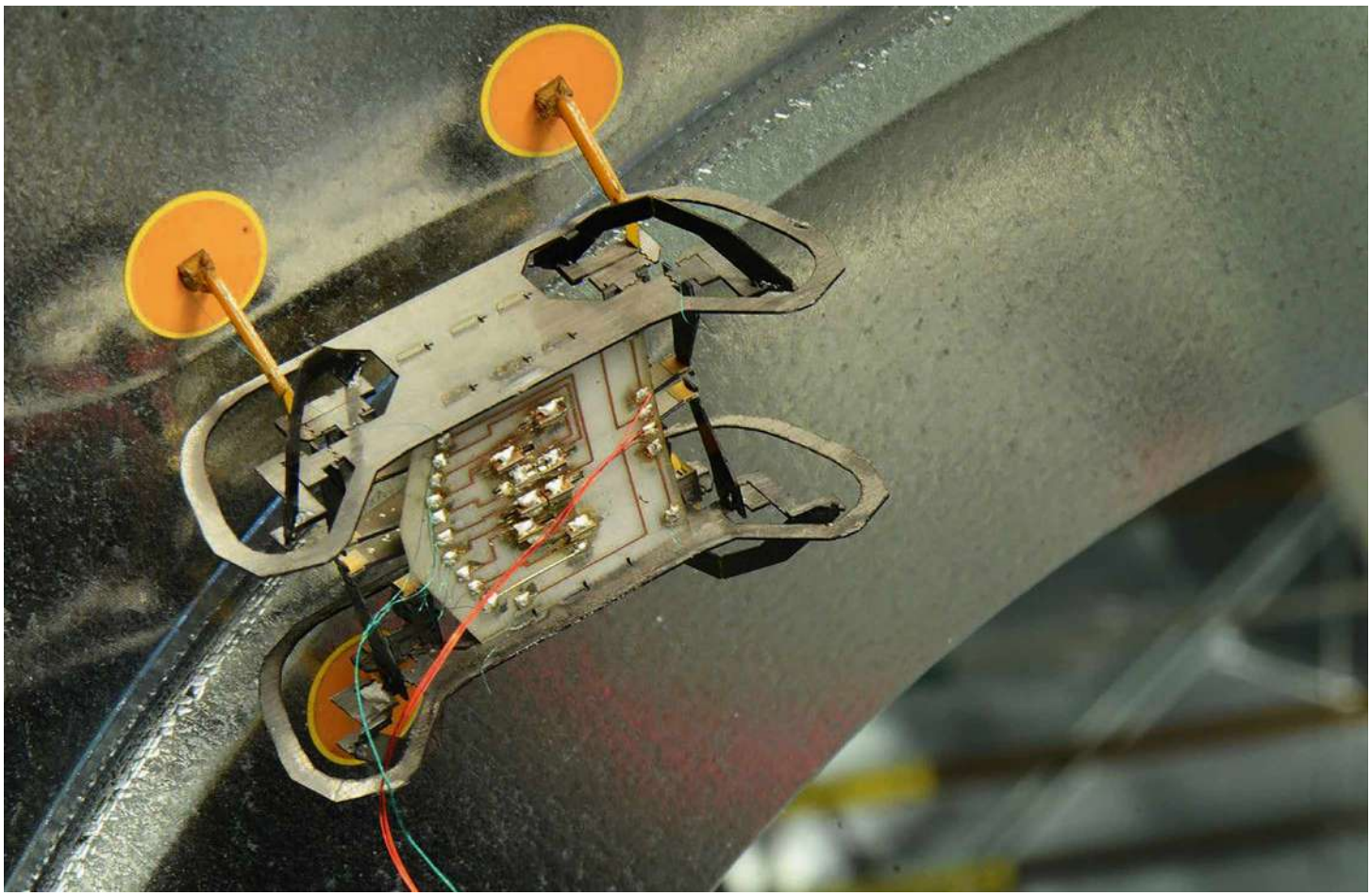
LARS SMOOK, DAVID BIERBACH

PUTTING THE (ROBOTIC) FALCON AMONG THE PIGEONS

A robotic falcon is helping researchers answer one of the most intriguing questions in animal behaviour: are animals naturally selfish, or do they try to protect the group as a whole? If the 'selfish herd' theory is to be believed then, when under attack from birds of prey, each pigeon in a flock should gravitate towards the centre of the group, using the protection of the crowd to save itself from being eaten. But that's not what happened when researchers from the UK and the Netherlands sent their robotic bird of prey into a flock of pigeons. Instead of crowding together, the birds aligned themselves with each other in a way that the researchers suggest could help the entire flock to escape from a real-life predator. "We find no support for a selfish herd hypothesis in pigeon flocks," they concluded in a *Current Biology* article published last year. Instead, they favour cooperative behaviour, which could have evolved because there is a decent chance of the whole group surviving, meaning, of course, that each individual survives too.

SPEED MERCHANTS

Fish are often perceived as having a raw deal in the intelligence stakes, but there is still much we have to learn about the complexities of their behaviour, particularly when it comes to their social interactions. That's why German researchers have been employing a robotic fish to help them understand collective behaviour in guppy pairings. Writing in the journal *Biology Letters* in 2020, the team explained that they moved a 3D-printed fish replica around using magnets attracted to a wheeled robot beneath the test tank. The robot was programmed to copy the speed and direction of the individual fish it was partnered with and to stay the same distance away. Watching how 20 different live guppies – some fast, some slower – behaved when followed by the robotic fish made the team realise how important swimming speed is in determining group dynamics. When the real fish swam faster, the pairs were better aligned and coordinated. According to the researchers, the study "highlights how both individual speeds and high levels of social responsiveness are important for the collective performance of groups."



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CLIMBING THE WALLS

It might have four legs instead of six, but this 4.5cm-long cockroach-like robot gets the most out of them, scuttling around and scaling walls like its insect counterparts.

Developed by Harvard University engineers, the 1.5g bot is based on an earlier design for miniature walking robots, and can climb vertical and curved surfaces, including parts from the inside of a jet engine. In fact, aircraft engine maker Rolls-Royce, which funded the work, specifically asked the team if they could design an army of tiny jet engine inspectors to reach the parts of the engine that humans can't. To meet their request, the engineers considered how insects like cockroaches climb walls using sticky pads on their feet. They designed foot pads for their microrobot based on electroadhesion, which works by inducing opposite charges on the surface and whatever is sticking to it. Although it remains on a tether that supplies its sticky function, not many robots with such small legs are capable of the feats of climbing that this little guy has achieved.

→

THE GO-BEE-TWEENS

Would bees and fish be friends? We'll probably never know, but they can make joint decisions – if they have robots to help them out. As weird as it may seem, in 2019, a team of engineers from four European universities managed to get Austrian honeybees to talk to Swiss zebrafish by sending in robot bees and robot fish – that they called 'agents' – to infiltrate their social groups. These robot go-betweens tailored their messaging to their assigned species, with the robo-fish using colours and tail movements, while a stationary bee robot (the white device in this image) vibrated and changed temperature to transmit information. The agents digitally conferred to coordinate the movements of the two species, which were actually 680km apart. Within half an hour they'd managed to synchronise their movements and even got them to adopt some of the characteristics of the other species, with the bees moving less as a swarm and the fish sticking together more than usual. **SF**

by **HAYLEY BENNETT**
Hayley is a science writer based in Bristol, UK.

KAUSHIK JAYARAM, ARTIFICIAL LIFE LABORATORY/UNIGRAZ

ARE WE ALONE IN THE UNIVERSE?

The search for alien life is ramping up. But what if, instead of searching for signs of biology, we looked for something more familiar: an extraterrestrial civilisation

by MARCUS CHOWN

ILLUSTRATION: MAGIC TORCH

In Arthur C Clarke's award-winning 1973 novel, *Rendezvous With Rama*, a mysterious 50-kilometre-long cylindrical spacecraft enters the Solar System. A space mission is mounted to intercept it and study it before it flies back out and is swallowed up by the darkness of interstellar space.

Now, remarkably, science fiction is morphing into science fact. Astrophysicist Prof Avi Loeb of Harvard University believes 'Oumuamua, a mysterious interstellar object that flew through the Solar System in 2017, may have been an alien *Rama*-like artefact. But being a scientist rather than a science fiction writer, he wants data. "With that in mind, I have set up Project Galileo," he says. "Its aim is to scan the heavens for the next 'Oumuamua and send a space mission to fly by it and photograph it."

More than 100 scientists, led by Loeb, are involved in Galileo. They are subtly shifting the emphasis of the Search for Extraterrestrial Intelligence (SETI) from looking for signs of alien biology or electromagnetic signals to hunting for objects as signs of alien technology. Loeb thinks this change is long overdue.

"For 70 years we've been barking up the wrong tree," he says, alluding to the 70-odd years astronomers have been searching for intelligent radio signals from our Galaxy. "That search is predicated on the assumption that extraterrestrials communicate via radio waves, a technology we have used for just over a century and which advanced extraterrestrials may have long ago left behind," he adds. "I think a better strategy is to look for artefacts: alien tech."

Not everyone agrees about this shift in emphasis of SETI. "However, I would agree, that so-called artefact SETI seems to have got more traction lately," says Prof Jason Wright, an astronomer and astrophysicist at Pennsylvania State University. He points out, though, that "very little searching is being done".

"THE MOON IS LIKE A MUSEUM. WE SHOULD SCOUR ITS SURFACE"

The best place to look for artefacts, says Loeb, is in the Solar System – our 'mailbox', where extraterrestrial 'packages' have been able to accumulate for 4.55 billion years.

MARMITE AND MONOLITHS

Alien technology could end up in our backyard either by design or by accident. In 1996, Dr Alexey Arkhipov of the Institute of Radio Astronomy in Kharkiv, Ukraine,

LEFT 'Oumuamua was discovered by the Pan-STARRS telescope in 2017. It was the first known interstellar object to visit our Solar System

BELOW LEFT The monolith from *2001: A Space Odyssey* was placed on the Moon by an alien civilisation to alert its makers when intelligent life evolved

BELOW Astrophysicist Prof Avi Loeb at Harvard University has set up Project Galileo to hunt for the next 'Oumuamua, fly by it and take photographs

into the extraterrestrial equivalent of consumer goods, Arkhipov concluded that the Earth, in its history, would have accumulated about 4,000 extraterrestrial artefacts the size of a Marmite jar.

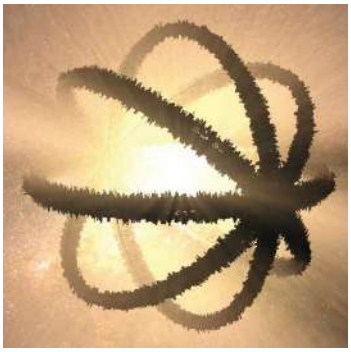
The Earth has weather and geological activity which re-mould its surface, so any alien artefacts would be very hard to find. But other bodies in the Solar System, with surfaces that do not change, like the Moon, would be a better bet. "The Moon is like a museum," says Loeb. "We should scour its surface for equipment we did not send."

Inevitably, this conjures up images of the film version of another of Clarke's stories, *2001: A Space Odyssey,* in which a buried alien monolith is excavated in the Moon's Tycho Crater. Left by extraterrestrials who passed through the Solar System millions of years earlier, it is a 'baby alarm', put there to warn its makers when life on the third planet from the Sun emerges from its terrestrial cradle and crosses the gulf

pointed out that bits of our own space technology are unavoidably ejected from the Solar System by events such as collisions in space and explosions, and that the same thing should happen in reverse, with material from alien spacefaring civilisations ending up in the Solar System. By estimating that 1 per cent of nearby stars have been home to technological civilisations and that, over their history, they turn 1 per cent of the material of their asteroids

ESO/M KORNMESSER, GETTY IMAGES, ALAMY

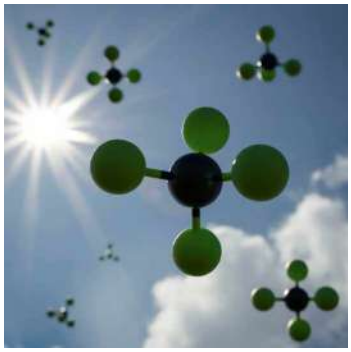
HELLO, IS IT ET YOU'RE LOOKING FOR?



MEGASTRUCTURES

Just as our global energy needs are always increasing, so too will the energy needs of an advanced alien civilisation. In 1960, Anglo-American physicist Freeman Dyson suggested that, eventually, ETs will want to use the entire energy output of their parent star. They might do this, he argued, by dismantling their asteroid belt and reconstructing it in the form of a spherical shell that completely encloses their sun. Not only would this provide tremendous amounts of energy, it would offer an enormous surface area – the interior of the shell – for living space.

A Dyson sphere would be unstable but an equatorial belt or a vast constellation of satellites could still intercept huge amounts of stellar energy. Such a structure might be detectable because the laws of thermodynamics predict that the intercepted starlight is emitted as heat radiation, or far-infrared. Also, a large number of bodies in orbit around a star might eclipse its light, causing it to fluctuate wildly. This was seen in the case of KIC 8462852 or 'Tabby's star'. Although this was explained by dust within our own Solar System, the possibility remains that the light of other stars might be variable in an unusual manner and explicable only by megastructures in close orbit.



INDUSTRIAL CHEMICALS

Human civilisation injects polluting chemicals into the atmosphere of Earth, and extraterrestrial civilisations may do the same. Such chemicals are not only potentially detectable but also unambiguously of intelligent origin.

If we observe a planet in a Solar System beyond our own, as the planet moves between us and its parent star, starlight will pass through its atmosphere and bites of light will be taken out at characteristic wavelengths of atmospheric chemicals. This allows astronomers to detect what substances are present in the planet's atmosphere. According to astrophysicist Prof Avi Loeb, some promising industrial chemicals to look for in these alien atmospheres are tetrafluoromethane (CF_4) and trichlorofluoromethane (CCl_3F). Both of these chemicals are refrigerants and are the two easiest chlorofluorocarbons (CFCs) to detect.

"If CCl_3F and CF_4 exist at 10 times current terrestrial levels, they should be detectable in 1.2 and 1.7 days of observing, respectively, with the James Webb Space Telescope [which was launched on Christmas Day 2021]," Loeb says.

of space to the Moon. Loeb says he is not fond of science fiction. Nevertheless, a lot of this ground has been trodden by writers like Clarke.

Recognising an alien technological artefact might not be easy. Alien civilisations could be as far from us in evolutionary terms as we are from ants. Or even bacteria. However, Loeb says if a caveman picked up a mobile phone, he would know it was different from a rock – though its purpose would be mysterious. "Similarly, we should look for things that differ from rocks," says Loeb. And he does not mean only on the surface of bodies in the Solar System, he means the space between the planets too.

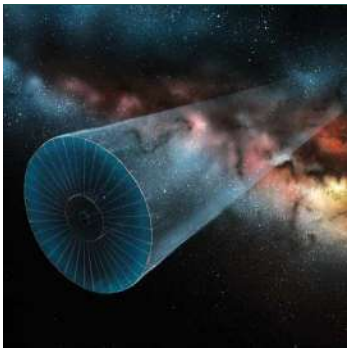
THE TROUBLE WITH 'OUMUAMUA

That was where 'Oumuamua was spotted in late 2017 by the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) at Haleakala Observatory in Hawaii. It was quickly recognised to be travelling too fast to be a body trapped by the Sun's gravity. 'Oumuamua wildly varied the amount of light it reflected, indicating it had an extreme shape, most likely that of a flat pancake the size of a football pitch.

The most striking thing about 'Oumuamua was that it wasn't moving like a body influenced solely by the Sun's gravity. Something was pushing it away from the Sun. Comets outgas material and this acts like a rocket exhaust, pushing them in the opposite direction. But Loeb says that 'Oumuamua showed no evidence of material being ejected.

Others, however, maintain it is impossible to rule this out. "The amount of outgassing needed to explain the acceleration would have been too little to have been detected," says Prof Chris Lintott, an astronomer at the University of Oxford. He also points out that, historically, several observations have claimed to be evidence of aliens before being shown to be natural. For example, the Martian moons Phobos and Deimos were thought to be hollow because of their low density, while pulsars were dubbed LGMs, for Little Green Men.

The existence of one object like 'Oumuamua from beyond the Solar System implies there should be others. And, in September 2020, 2020 SO was discovered by Pan-STARRS.

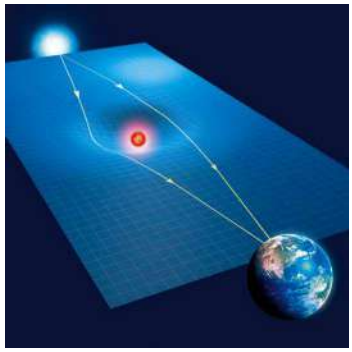


LIGHT SAILS

Aliens will face the same problem as we do if they cross interplanetary or interstellar space. Large amounts of fuel are needed in order to drive a spaceship. But this problem goes away if the spaceship's power source is left at home.

This was the proposal of Robert Forward of Hughes Research Laboratories in Malibu, California. In 1984, he described a laser-pushed light sail. A payload would be attached to a large, ultra-thin sail of reflective material and this would be pushed by a solar-powered laser based in the Solar System. Forward calculated that a one-tonne probe attached to a 3.6km-wide light sail could be accelerated by a 65GW laser to 11 per cent of the speed of light and fly by the nearest star system, Alpha Centauri, in just 40 years.

This idea has been recently revived for the Breakthrough Starshot programme. It's at an early stage, but the aim is to use a 100GW laser array to push a far more modest, one-gram (!) payload to 20 per cent of the speed of light and flyby and photograph the planet around Proxima Centauri. If ETs use similar laser-pushed light sails to zip around their planetary systems or the Galaxy, we may be able to pick up the flashes of light when their lasers are turned on and off.



WORMHOLE TRANSPORT SYSTEMS

A sufficiently advanced civilisation might be able to manipulate space-time itself to create wormholes. These shortcuts through space-time – which are permitted to exist by Einstein's theory of gravity – could enable a galaxy to be crossed in the blink of an eye. Intrinsically unstable, a wormhole would need 'stuff' with repulsive gravity to hold open each mouth, and the energy equivalent to that emitted by an appreciable fraction of the stars in a Galaxy. We know such stuff exists because it is speeding up the expansion of the Universe in the guise of dark energy, though its gravity is too weak to prop open a wormhole.

If ETs have created a network of wormholes, it might be detectable by gravitational microlensing. This occurs when a celestial object passes between us and a distant star and its gravity briefly magnifies the light of the star. If the object is a wormhole, the pattern of brightening and fading of the star is distinctly different, according to Prof Fumio Abe of Nagoya University in Japan. "If the wormholes have throat radii between 100 and 10 million kilometres, are bound to our Galaxy, and are as common as ordinary stars, detection might be achieved by reanalysing past data," he says.

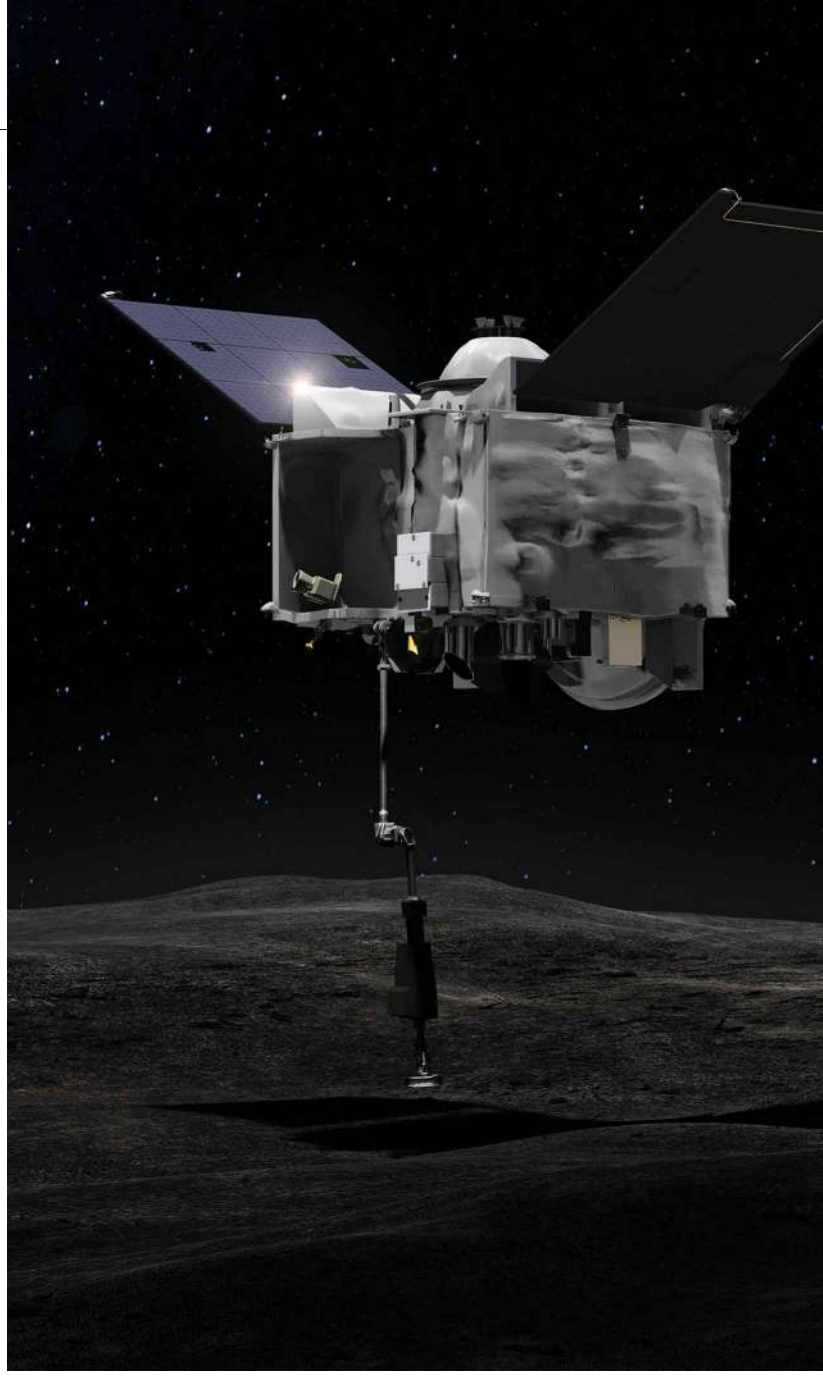
Like 'Oumuamua, it was being pushed from the Sun without apparent cometary outgassing. However, when astronomers tracked its orbit back through time, they found that the intelligent civilisation it had come from was none other than… ours! 2020 SO appears to be the discarded Centaur upper stage of the rocket that propelled NASA's Surveyor 2 lander to the Moon in 1966.

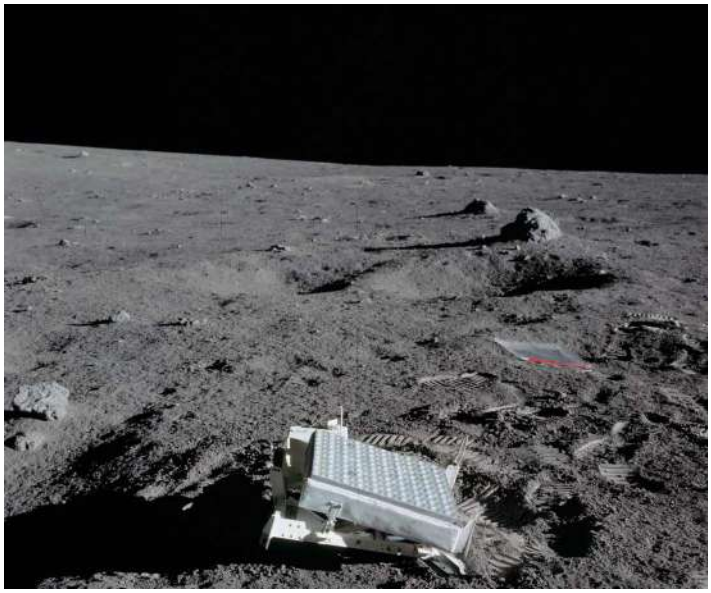
Not surprisingly, Loeb's suggestion that 'Oumuamua was an alien artefact was controversial. Loeb found it odd that astronomers were prepared to propose exotic things never seen before such as a hydrogen iceberg, a chip of frozen nitrogen or a cloud of dust particles 100 times more rarefied than air, but were upset by the suggestion that 'Oumuamua may have come from an ET civilisation.

"One astronomer even said "Oumuamua is so weird. I wish it hadn't existed," says Loeb. Meanwhile, Loeb was wondering, ➔

LEFT The Pan-STARRS telescope in Hawaii spends the majority of its time hunting for near-Earth objects

GETTY IMAGES, ALAMY X2, SCIENCE PHOTO LIBRARY, R RATKOWSKI





RIGHT OSIRIS-REx travelled to the asteroid Bennu to scoop up a sample to bring back to Earth. Astrophysicist Prof Avi Loeb argues that similar technology could be used to touchdown on a second 'Oumuamua

BELOW RIGHT Astronauts placed equipment on the Moon, such as this laser reflector left behind by Apollo 14, but we should attempt to scour the lunar surface for items of an extraterrestrial origin

"Who built 'Oumuamua? Could it be a piece of garbage? Might it be merely the skin of a larger vehicle that broke up?"

THE EXPLORERS

Loeb is convinced the search within the Solar System for more objects like 'Oumuamua – and even much smaller – is worthwhile. And now he has the seed money to do it. It came about because Bill Nelson, head of NASA, gave a speech on 3 June 2021 in which he said a scientific analysis was needed of Unknown Aerial Phenomena (UAP) detected by a multitude of instruments. UAP are actually UFOs, renamed to remove the stigma. Former president Barack Obama called UAP "a serious matter". On 5 June, Loeb emailed NASA to suggest the kind of scientific project Nelson was advocating but received no reply.

But while one door remained closed, another opened. The COVID-19 lockdowns have been a great opportunity for Loeb to stay at home and think. He has written many scientific papers, a bestselling book about 'Oumuamua called *Extraterrestrial* and a huge textbook, *Life In The Cosmos: From Biosignatures To Technosignatures*, with his former postdoctoral researcher Manasvi Lingam of the Florida Institute of Technology. "One of the nice things is that many people have visited the porch of my house," he says. "One, who came a few weeks after I sent my email, was Frank Laukien, CEO of Bruker Corporation, a Massachusetts-based manufacturer of scientific equipment."

Laukien and other visitors donated a total of $2m: the money Loeb used to establish the Galileo Project, which was announced on 26 July. The project has two strands. The first, which Loeb envisages costing $100m, is to identify the nature of UAP. A battery of optical and infrared video cameras, radio and audio sensors will be installed on the roof of Harvard College Observatory in spring 2022 to monitor the sky 24 hours a day, with objects in the data being identified with artificial intelligence algorithms. The goal is to have many batteries around the world, scanning as much sky as possible. Loeb calls it a "fishing expedition" and says it is an attempt to inject sanity into the subject by bringing it into the scientific mainstream.

Things are moving on other fronts too. In December 2021, President Joe Biden created a new office, under the Department of Defense, to assemble data from all branches of government to get to the bottom of UAP.

The second strand of Galileo, which is envisaged as costing $1bn, is more ambitious. It is the search for the next 'Oumuamua and the design of a robotic mission to intercept its trajectory and take close-up photographs. This, Loeb admits, will be hard. "If we were to detect an intelligent

LEFT A map of the asteroid Bennu's surface, taken by OSIRIS-REx

radio signal from the nearest star, there would be little hurry to reply since the round-trip communication time would be a decade," he says. "But, if we spot something in the Solar System, we will have to move extremely quickly. 'Oumuamua was gone before we had much time to study it."

Even a mission to land on a second 'Oumuamua may not be out of the question. NASA achieved this in 2018 by landing its OSIRIS-REx spacecraft on asteroid Bennu and scooping up a sample, which returns to Earth in 2023.

"If there is alien tech, it may represent more than a scientific opportunity," says Loeb. "It could also be a business opportunity for importing the new technology to Earth!"

Lintott says that: "If Project Galileo gets people excited about understanding interstellar objects entering the Solar System that would be fabulous." He says the European Space Agency is already planning the Comet Interceptor mission, which will be able to fly to a body like 'Oumuamua. "The plan is for it to lurk in space waiting for a suitable target, whether that turns out to be a comet visiting the inner Solar System for the first time or an interstellar object."

All this focus on the Solar System may appear reminiscent of a drunk who has lost his car keys at midnight and is searching for them under a streetlight – not because that is where they are likely to be found but because that is the only place he can sensibly look. Nevertheless, Loeb thinks it is worth carrying out a thorough search of our backyard because nobody has yet.

"In the words of Robert Frost, it is taking 'the road less travelled'. And, whenever you do that, there is always the possibility of finding low-hanging fruit," he says.

> "IF WE SPOT SOMETHING IN THE SOLAR SYSTEM, WE WILL HAVE TO MOVE QUICKLY. 'OUMUAMUA WAS GONE BEFORE WE HAD MUCH TIME TO STUDY IT"

DEEP SPACE

Looking beyond the Solar System is harder. But Loeb thinks that searching for technosignatures is still a better bet than looking for biosignatures of microbes, the principal aim of astrobiologists. The main biomarkers are oxygen and methane, both of which can exist in a planetary atmosphere only if they are constantly replenished. Currently, more than ➔

NASA/JPL X2, NASA/KSC

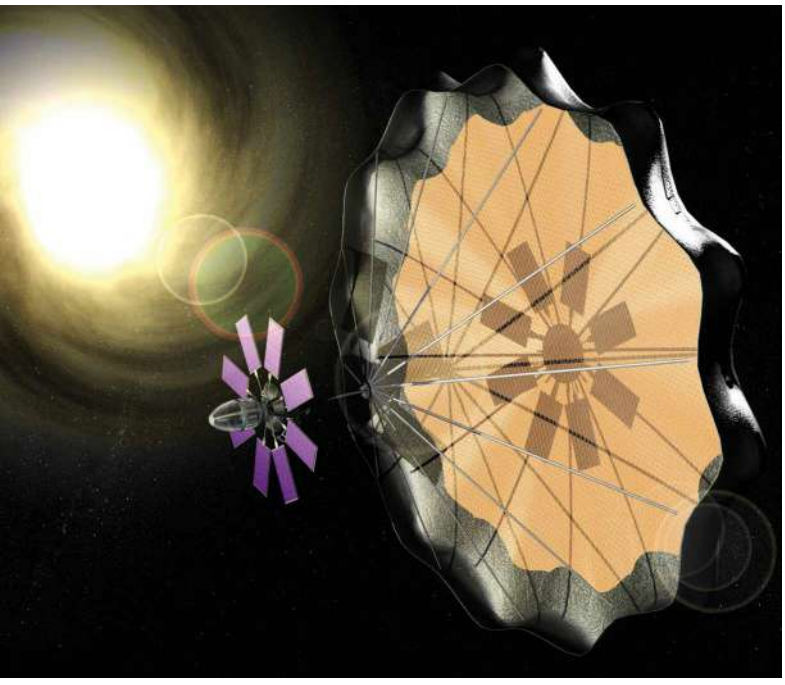
4,000 planets beyond our Solar System are known. As they orbit their parent stars, some pass between the star and Earth, so starlight passes through their atmospheres. Oxygen and methane take bites out of the starlight at characteristic wavelengths which are their 'spectral fingerprints'. "The problem," says Loeb, "is that for the first two billion years of life on Earth there was little oxygen in the atmosphere. And both oxygen and methane can have non-living sources."

A better bet, Loeb believes, is to look not for the chemicals of biology but of technology. He suggests compounds like chlorofluorocarbons, or CFCs – once used on Earth as refrigerants and spray-can propellants, and famous for their ozone-layer-destroying properties. "They could be detected in the atmosphere of planets around nearby stars by NASA's 6.5-metre James Webb Space Telescope," he says.

But there are other signs, such as alien megastructures. For a time, it looked as if KIC 8462852, also known as Tabby's Star, was fluctuating wildly in brightness and it might be orbited by such structures, possibly giant starlight collectors. But the behaviour of the star turned out to be the result of dust in the Solar System.

Loeb says that light sails pushed by mega-lasers are a plausible means of extraterrestrial transport, and we might detect the overspill of such light. Also, if an alien civilisation collected starlight by covering its planet with photovoltaic panels, it would cause its surface to reflect light differently from rock and ocean. By a piece of good fortune, the nearest star, Proxima Centauri, has a planet. The planet, Proxima Centauri b, is 20 times closer to its star than Earth is to the Sun. But because Proxima Centauri is a cool, red dwarf star that's 500 times less luminous than the Sun, the planet is potentially habitable. Like our Moon, the planet is tidally locked, causing one side to be in permanent day while the other is in permanent night. "An alien civilisation might live on the night side but cover the light side with photovoltaic panels," says Loeb. About 0.1 per cent of the Earth's surface is illuminated with artificial lights, but Loeb estimates that if 10 per cent of Proxima Centauri b's night side is similarly illuminated, this would be detectable from Earth by the James Webb Space Telescope, which was launched on Christmas Day.

"EXTRATERRESTRIALS MAY HAVE DECIDED TO STAY AT HOME AND LIVE IN A CYBER COCOON, LIKE FACEBOOK'S PROPOSED METAVERSE"



BELOW Light sails propelled by enormous lasers could be a feasible way for aliens to travel around the Universe, and it may be possible for us to detect such light sources

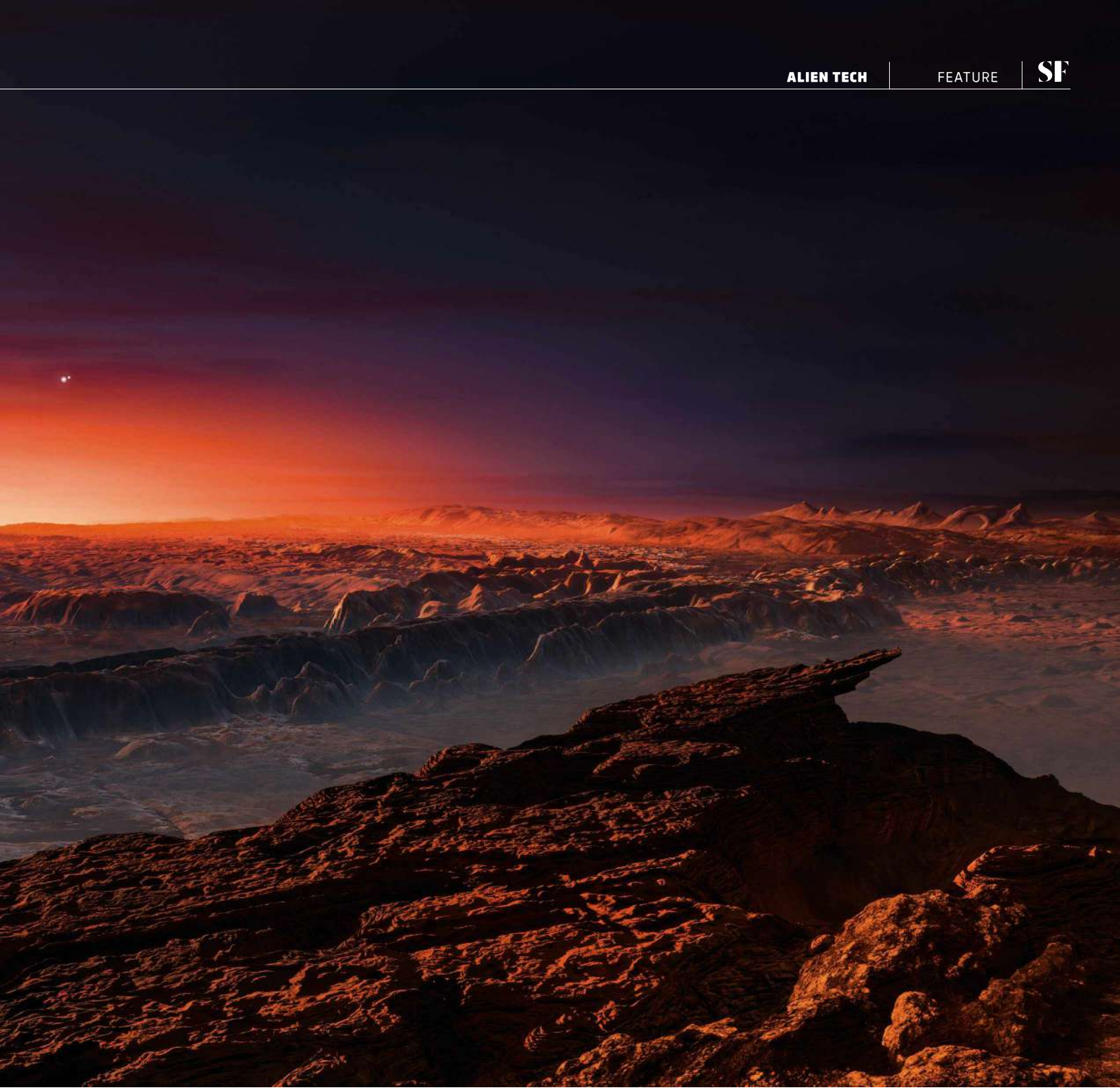
SHY ALIENS

Loeb accepts the possibility that extraterrestrials may be very difficult to find. They may be hiding, for instance, because it is a dangerous Universe and, if you signal your presence, you get wiped out. If so, it might be too late for us since our radio broadcasts have already reached thousands of nearby stars!

But even if ETs are not hiding, they may have decided to stay at home and live in a cyber cocoon, like Facebook's proposed Metaverse. This is another possibility anticipated by Clarke in his 1949 novella, *The Lion Of Comarre*, which described a future in which for many the virtual world is more seductive than reality.

Of course, aliens who are millions or even billions of years ahead of us in evolutionary terms are likely to be, as Clarke pithily observed, "indistinguishable from magic".

"A sufficiently advanced intelligence might even be a good approximation of God," says Loeb. "It would be able



SCIENCE PHOTO LIBRARY, ALAMY

to create life from non-life and maybe even manipulate laws of physics to make new universes."

What might be the benefits of finding advanced extraterrestrial artefacts? Well, we would know it is possible to survive planetary cataclysms such as global warming. Hopefully, we would be inspired to keep pushing forward the frontiers of scientific knowledge.

Most importantly, says Loeb, knowledge of the existence of an alien civilisation would make differences between people on Earth appear trivial. "In the 20th Century, denial of this caused the deaths of 3 per cent of the world's population at the hands of the Nazis and others," says Loeb. "ETs would show us more unites us than divides us."

ABOVE Artist's impression of Proxima Centauri b, the potentially habitable planet orbiting our nearest star

As for the chance of finding an ET artefact, Wright confesses: "I don't know!" Loeb, however, is more optimistic. "Most stars formed billions of years before the Sun," he says. "For that reason, I think the chances are very good." SF

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by **MARCUS CHOWN** *(@marcuschown)*
Marcus is author of Breakthrough: Spectacular Stories Of Scientific Discovery From The Higgs Particle To Black Holes *(£9.99, Faber & Faber).*

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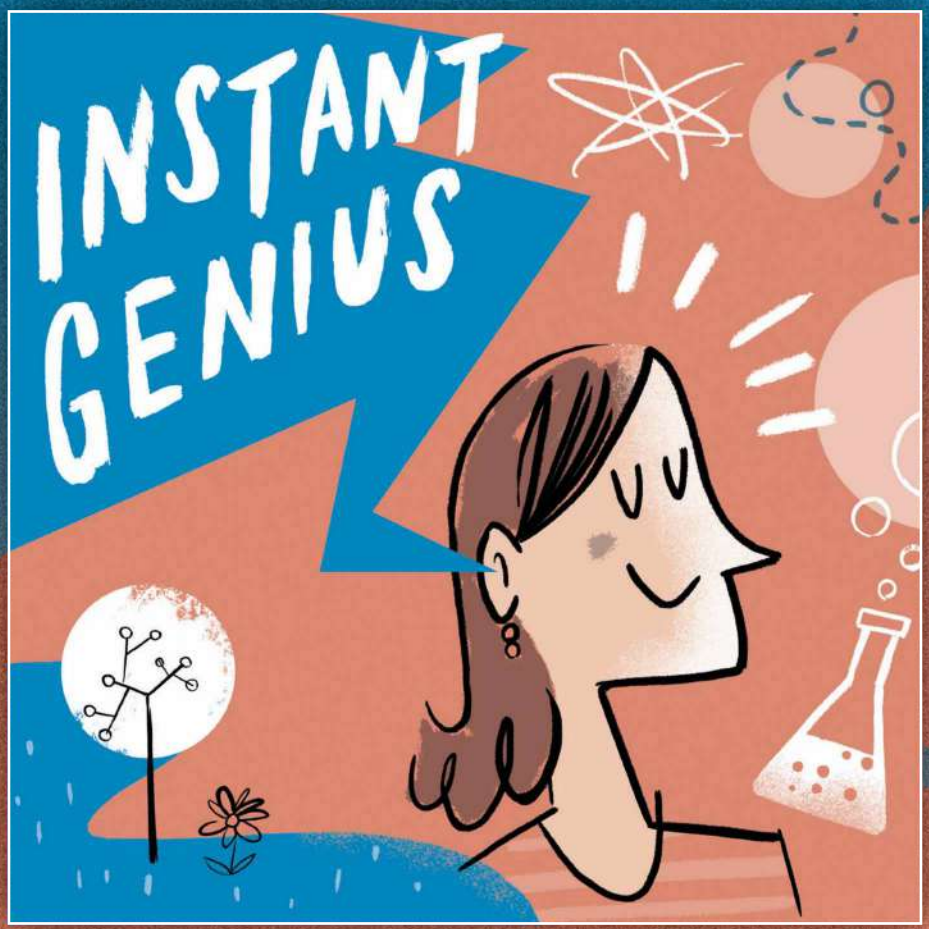

FEATURING

HEALTH HACKS — *with* ***Dr Michael Mosley***

PSYCHOLOGY OF EVIL — *with* ***Dr Julia Shaw***

EATING FOR YOUR BRAIN — *with* ***Kimberley Wilson***

THE NATURE OF TIME — *with* ***Colin Stuart***

ILLUSTRATION: ADAM GALE

COMMENT

WHY WE NEED TO EAT MORE PROTEIN

Load up on eggs, tofu, Greek yoghurt, fish and lean meat to help you feel full for longer

As you have probably noticed, in the world of diets there is an ongoing battle between fans of low-fat foods and those who prefer to embrace a low-carb lifestyle. Yet as I discovered when I began researching my latest book, *The Fast 800 Keto*, the biggest driver of appetite is that other macronutrient: protein.

Eggs, fish, meat and tofu are all rich in protein and help build muscles, enzymes and much of the infrastructure of our bodies; eating enough of it is absolutely vital for growth and repair. And as two leading Australian academics, Prof David Raubenheimer and Prof Steve Simpson, argue, lack of protein is one of the major drivers of the current obesity epidemic. If you don't get enough protein in your diet, then you will develop cravings and overeat in a largely unconscious attempt to hit critical protein targets. They say that we need to consume around 15 to 20 per cent of our daily calories in the form of protein. This amounts to around 100 grams of protein, if you are eating the normal 2,000 to 2,500 calories a day.

According to their 'protein leverage hypothesis', the main reason we are getting fatter is because we are surrounded by ultra-processed foods that are typically rich in fats and carbs but low in protein, so we overeat to try and satisfy our protein hunger.

"The volunteers ate, on average, 210 calories more per day when they were on the low-protein diet"

They first demonstrated the power of this theory with an elegant experiment published in 2011 in the journal *PLOS One*. They recruited 22 healthy volunteers and on three separate occasions the volunteers were invited to stay in hotel-style accommodation in Sydney University for four-day visits. While they were there, their meals were provided, but they also had access to lots of different snacks. The volunteers didn't know the real purpose of the experiment and they weren't told that their meals, although matched for calories, contained different levels of protein.

On one of their four-day visits, the meals contained 10 per cent protein, on the next it was 15 per cent and on the third it was 25 per cent. Would this make any difference to how much the volunteers ate? Well, without realising it, the volunteers ate, on average, 210 more calories per day when they were on the low-protein diet than they did on the high-protein diet. Do that on a regular basis and you would soon find yourself piling on the weight.

The volunteers also reported feeling hungrier a couple of hours after eating the low-protein breakfast, despite eating the same number of calories as on higher protein days. That is certainly what I find. When I eat eggs or fish for breakfast, I stay full until lunchtime. But if I eat the same number of calories in the form of cereal or toast, I am craving a snack by mid-morning.

The current government guidelines are to eat around 50g of protein a day, which I think is way too low, particularly for people as they get older (you need more protein after the age of 60 because your body is less able to absorb and utilise it). For high-protein breakfast inspiration, visit **bit.ly/protein_brekkie SF**

MICHAEL MOSLEY

Michael is a health writer and broadcaster, who presents *Trust Me, I'm A Doctor*. His latest book is *The Fast 800 Keto* (£9.99, Short Books).

BBC TWO

PORTRAIT: KATE COPELAND ILLUSTRATION: CHRISTINA KALLI

BBC TWO
The new series of *What We Do In The Shadows* is out later this year. Catch up on BBC iPlayer.

COMMENT

DECISIONS, DECISIONS

None of us can peer into the future to see how life-changing decisions will pan out, but we can find joy in our new lives once we make the leap

ALEKS KROTOSKI
Aleks is a social psychologist, broadcaster and journalist. She presents *The Digital Human*.

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There are times in a person's life when they stand on the edge of a precipice. Or maybe at a fork in the road. Perhaps they're sitting on a fence. Whatever metaphor about decision-making you prefer, the big decisions are the most unpredictable because there's no way of knowing who we will be on the other side. Take, for example, deciding to become a vampire.

In the magnificent TV series *What We Do In the Shadows*, Guillermo is the only human living with four vampire housemates. He is a 'familiar', a servant-slash-slave who turns out the lights during the day and disposes of the bodies when his undead housemates have finished with them. He does this because his master, Nandor the Relentless, has promised to make him a vampire. God, he wants it so much.

But Nandor's evasive. He doesn't see it like Guillermo does. Nor does he see it like he did 759 years ago, when he became a vampire. Sure, he can do cool things like fly and explode objects into flames. But the rest of it? To Nandor, he misses his old life. He wants to be human again. Being a vampire is a curse.

According to philosopher Laurie Ann Paul, the vampire story is a psychological fairy tale about making big transformative decisions. In 2014, she wrote a book explaining that there is no way to predict how you will respond to a decision until you've made it because you will be so transformed that you won't know yourself. It's equally impossible for someone on the other side to explain what it's like to be there.

"Choosing to become a vampire is forever. Like joining a religion. Or becoming a parent"

Now, becoming a vampire isn't all that common. If it were, a living person who was considering that path would be able to browse bookshelves crammed with *What To Expect...* guides, and hire consultants to help before, during and after. But even those wouldn't prepare a person for their undead eternity, explains Paul. Choosing to become a vampire is forever. Like joining a religion, or transforming your physical appearance, or your mental state. Or becoming a parent. There's no going back.

I have a friend who has got a two-year-old. It's not been an easy couple of years. She's starting to see the joy now, which is joyful for everyone around her who's already been through their version of those neverending 24 months. Her sister is about to give birth for the first time. "I warned her," said my friend, only half joking. Yes, I laughed. And I warned you. My friend didn't remember my warning, just as I didn't listen to another friend's warning, who eventually held my hand as I came to terms with how fundamentally life had changed. I don't know if vampires do this too, but we humans have a remarkable ability to hear things through our feelings.

The fourth series of *What We Do In The Shadows* is landing soon, so we don't know yet whether Guillermo will become a vampire. But whether he does or not, I predict he'll somehow be instrumental in helping Nandor find joy in his undead life. It's how these stories usually go. Because there is no going back. It just takes time to remember again who you are. SF

PORTRAIT: KATE COPELAND ILLUSTRATION: SCOTT BALMER

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BBC SOUNDS

An Artificially Intelligent Guide To Love is an experimental drama and collaboration between a human writer (Hannah Silva) and AI. Listen on BBC Sounds.

ME, YOU, AND INTIMACY TOO

When was the last time you were intimate with someone, emotionally, intellectually, or physically? Psychologist **Dr Michelle Drouin** says we are in an intimacy famine, and speaks to **Amy Barrett** about whether social media and smartphones are stripping us of one of our basic human needs

ARE WE REALLY IN AN INTIMACY FAMINE?

It sounds dire, but potentially, yes. Many of us are not going to work in the offices that provided us with exposure to people with whom we shared social, emotional and intellectual intimacy. We are not even smiling at people, because our smiles are disguised by masks [due to the pandemic]. The smile that we give another human could be a type of emotional intimacy for them, or a connection to a world that is happy and good, where people are supportive of each other.

When we get home, our children, our partners, whomever is at our house, might be threats to us. We have something called the behavioural immune system, which was studied before the pandemic, that says our bodies have a natural tendency to avoid potential pathogens. If we think someone is sick, we physically back away from them. It's basically a turnoff when we know someone could be a threat to our physical wellbeing.

Prior to the pandemic, studies pointed to changes in our intimacy levels. A 2019 study I worked on with family scientist Brandon McDaniel found that 72 per cent of couples felt a 'technoference' in their relationship.

Millions of people are lonely worldwide – one study reports prevalence rates of one in every five adults in the US and the UK, and one in ten in Japan – and loneliness has a profound, negative effect on mental and physical health.

Are we in an intimacy famine? I think so. We are at a place where it is harder to have intimacy than ever before.

DOES THIS MEAN THAT AROUND THE GLOBE, HUMANS ARE BECOMING LESS INTIMATE?

There are trends that point to the idea that we are not bonding in ways that maybe I would have considered bonding 30 years ago.

Look, for example, at marriage trends. The United Nations maintains world marriage ➤

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data from 232 different countries, and between 1970 and 2014 there was clear evidence that the number of married people is declining. For the under 30s, the percentage of those ever married has gone from 70 to 60 per cent in men and 90 to 80 per cent in women. The data also tells us there are more people divorced, separated or widowed now.

There are a lot of reasons why we have more single people than ever, so in general that is not anything negative. While there seems to be some positive health implications to being married, specifically for men, having good friends can have the same effect. Having very close contacts is something that's a predictor of longevity and a happy life.

DOES IT REALLY MATTER THAT FEWER PEOPLE ARE GETTING MARRIED?

People who are married do have sex more often than single people. Sex is a type of intimacy.

But lots of things count as intimacy. There's intellectual intimacy; the challenging of ideas and the intellectual exploration that we share with others. There's spiritual intimacy. There's emotional intimacy.

The physical intimacy that people automatically think about is just one part of what I see as an entire rainbow of intimate moments that we can have as human beings in our lifetime.

"Researchers exposed people to viruses and found that the people who'd had more hugs in the previous week were less likely to get sick"

IS IT A BIGGER PROBLEM FOR MILLENNIALS?

Millennials are having less sex than people of previous generations at that age, and yes, I think they have fewer committed relationships. Because of that you have fewer opportunities to have sexual relationships. You'd think there is a 'Tinder culture' where everyone is out having sex when they're single, but that's not true. And that's not true pretty much regardless of age.

Social media doesn't seem to be filling that void, unfortunately. In a US study of young adults, those in the top 25 per cent of social media use were twice as likely to feel socially isolated than those in the bottom 25 per cent.

But when I look at my children's lives compared to my life, their intimate

ABOVE The pandemic made people more cautious about being intimate with loved ones, due to concerns about spreading or catching COVID-19

GETTY IMAGES, NATALIE KUNKEL

ABOVE Dr Michelle Drouin researches psychological issues related to communications technology and social media

experiences are somewhat different. Whereas I used to spend an hour talking on a landline with a friend, my two teenage boys are playing an online game, communicating with friends through headphones and a microphone. Although that's a different type of intimate experience than I had when I was a child, I don't know if it's less intimate.

Maybe these conversations that they're having – ones that I don't think are deep and meaningful – are actually laying the foundation for the type of communication they'll need to do when they're in the workplace, 10 years from now. Maybe the majority of people will be doing remote work and them being accustomed to what we're doing right now is what they need in order to be successful, happy and fulfilled in that world.

THINKING ABOUT PHYSICAL INTIMACY IN PARTICULAR, WHAT ACTUALLY HAPPENS TO US WHEN WE ENGAGE IN SOMETHING INTIMATE?

Physical touch has profound effects on the body. Look at hugging. I always say you should hug for at least 20 seconds, because that's when all the feel-good neurotransmitters and hormones will hit us. Even hugging a pet for 20 seconds has a really good effect on the body. A hug releases oxytocin, a hormone that can lower your blood pressure and heart rate.

There is even a lot of research that shows that a hug can make you more resilient against illness. In experimental scenarios, researchers exposed people to viruses and found that those who'd had more hugs in the previous week were less likely to get sick.

It's good for our cardiovascular system to have sex with others. It's good for our brains. It releases a lot of feel-good hormones.

There are a cascade of positive changes that happen in the body when we have physical touch that are really supported by science.

HOW IMPORTANT IS PHYSICAL INTIMACY, COMPARED TO SOMETHING LIKE EMOTIONAL INTIMACY. DO WE HAVE TO HAVE A MIX OF THE DIFFERENT TYPES IN ORDER TO FEEL FULFILLED?

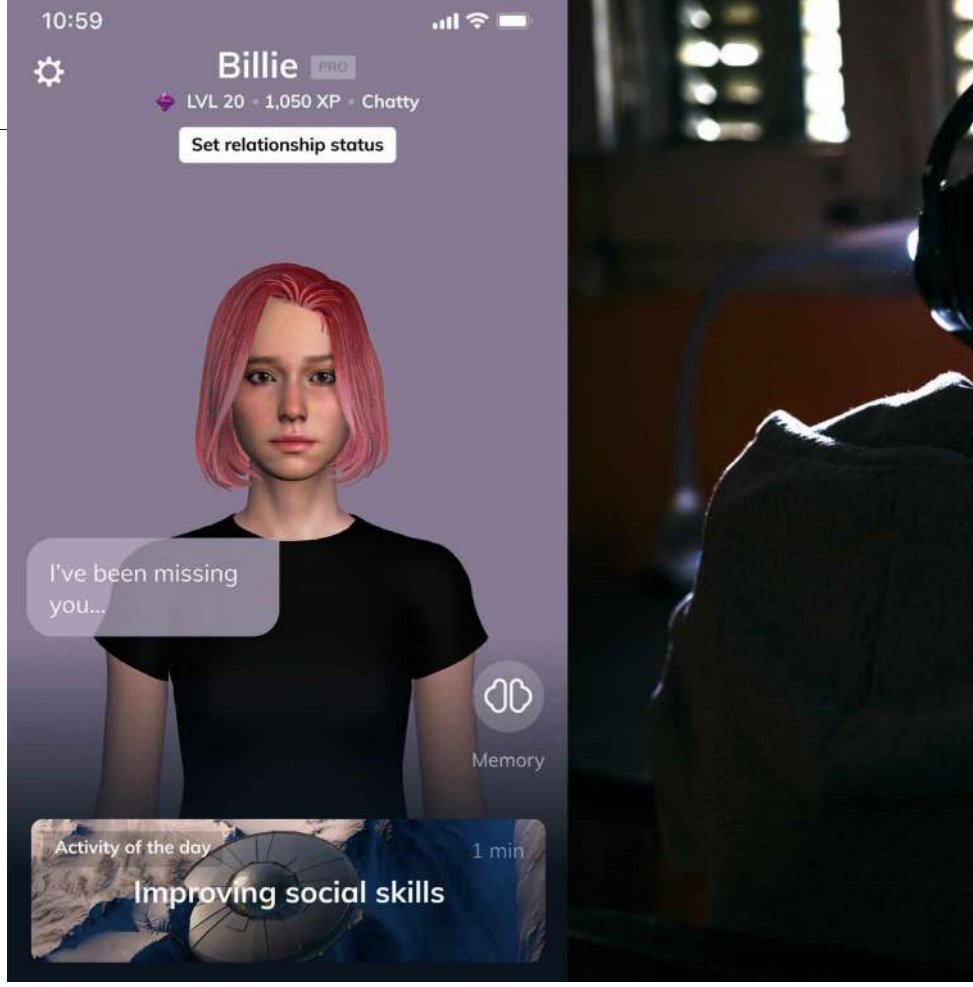
I don't think that science can give a determining opinion on it.

Some people might not have any physical intimacy in their lives, but have a lot of emotional intimacy and they feel completely fulfilled. Others might really need that physical intimacy. It all depends whether or not each of those things is important to you.

I will say that people who feel they're missing that physical intimacy aspect of their relationship – even people who are really emotionally fulfilled otherwise – will feel a vacancy in their lives. There's a TEDx talk on sexless marriage that has been watched by millions of people. Looking at Google Trends, more people are searching 'sexless marriage' than things like 'cheating in a relationship'.

EVOLUTIONARILY SPEAKING, HOW FAR DOES THIS NEED FOR INTIMACY GO?

There are some experiences that are different when we look at the animal kingdom. There ➔



is this idea that humans are unique in the way we hold on to psychological stress. Neuroscientist Robert Sapolsky studies stress. In Kenya, where he does his research, he says you can look at an antelope, running for its life. That's its moment of stress. And when that's over, it's done. You feel fine. But humans torture themselves with the psychological stress that they carry.

Our developed cerebral cortexes mean that we might interpret things differently to other vertebrates who don't have as developed brains as we do. Prof Robin Dunbar, an evolutionary psychologist at the University of Oxford, has this idea called the social brain hypothesis. He says that the reason humans have larger brains than all other vertebrates is because we are these social beings, and to interpret our social worlds, we had to develop bigger brains.

So, right now you might be thinking "I wonder what Michelle thought of me," and then I can wonder about what the readers will think about our conversation.

We can create just infinitesimal numbers of connections, things to think about in our social world, and that has helped us develop pretty advanced cognitive skills.

DO YOU THINK THAT TECHNOLOGY COULD EVER REPLACE INTIMACY?

Not necessarily physical intimacy, but I recently completed a study where people communicated online with an artificial intelligence, called Replika, or a human via instant messaging, or had a conversation with a human face-to-face.

I wanted to see what the participants' enjoyment was across each situation, and I found overall people were happy talking in all three ways, but they did feel closer bonds with those they met with face-to-face and they wanted to spend more time with that person.

Both of the human situations – instant messaging and face-to-face – were favoured over the AI. Something that was interesting, though, is that people said they weren't as concerned that they were being judged with the Replika AI. There's some beauty in that. That the presence of an AI friend means that you may have a non-judgmental party who can be witness to your life and who could be positive and supportive. That's something that will be interesting to explore in the future. But to directly contrast an intimate conversation via text message with the intimacy of physical touch... we just don't have those comparisons yet.

PEOPLE HAVE TRIED TO PIN THIS 'INTIMACY FAMINE' ON MODERN TECHNOLOGY, DO YOU THINK THAT'S FAIR?

I do believe that we've unfairly shunned these technologies, because we're currently in this very strange developmental period for how these technologies can be used to enrich us, how could they be used for social good.

What's happened – what always happens – is that technology advances more quickly than we can do research. So we're in this awkward teenage angst stage of technology. But I do believe we'll get to a good place.

Ultimately, technology does allow you to fulfil social needs. Absolutely. That's probably why we're also addicted to our phones, because we have basic needs for socialisation and it's easy to meet those needs when we pick up our phones and text a friend.

What I would argue is that we need to harness the technology of these phones to then make deeper connections. Use them as the entry point, but also don't miss out on those experiences that have defined us as humans.

HOW CLOSE ARE WE TO HAVING A ROBOT THAT COULD GIVE US INTIMACY?

I think we're probably a lot closer than people think to having very lifelike robots.

ABOVE LEFT Dr Michelle Drouin carried out a study where people could communicate online with this AI, called Replika

ABOVE RIGHT Communicating online with friends while gaming is a different kind of intimacy to chatting on the phone, but could help build communication skills for a world of remote working

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> **“Something about the anonymity or the asynchronicity of being online can make us feel like we can say things quicker than we might in a face-to-face context”**

ARE WE TALKING YEARS? DECADES? LIFETIMES?

I wish I could anticipate that! Right now, artificial intelligence is not at the deep level it needs to be for these robots to really think on their own. The conversations that they have – while not completely stilted – there are times when they trip up.

I think we'd need that technology advancing at the same pace as the anthropomorphism, the animatronic aspect, is advancing.

I don't know, I'd be guessing. It could be decades. I would be excited to see it in my lifetime but I'm not sure that that's going to happen. But even the movement that we have made in the past decade has been amazing.

WHEN HUMANS SEEK ANY INTIMATE CONNECTION, THERE'S ALWAYS A CHANCE OF REJECTION. BUT WHEN PEOPLE INTERACT WITH AI, THAT WEIGHT IS LIFTED – IT'S EASIER TO BE ANONYMOUS ONLINE.

Yes. Prof Joe Walther has done a lot of research in communication, and found that online we are hyperpersonal so we can actually get close really quickly to people online.

That's important, too. Online interactions can feel very deep. Something about the anonymity or maybe the asynchronicity of being online can make us feel like we can say things quicker than we might in a face-to-face context. Maybe it erases some of our fear of negative evaluation. That's a positive. I think that's also something that points to future benefits of artificial intelligence. Imagine having a partner who's always there, who is always giving you positive affirmations. You are not afraid the AI is going to yell at you, or berate you, or tell you that you're not worthy. It's just a being that's there to support you, to care about you, to bring interest to your life. I think it really points to one of the potential benefits of AI.

That said, once that is integrated in our lives, I'm not sure that humans will stack up. If I can have a friend who's always supportive and complimentary and bringing me unlimited amounts of interest, how will humans ever measure up? It'll be a difficult challenge. We'll have to raise our game.

TRUE. BUT THAT COULD QUICKLY BECOME BORING. SURELY PART OF WHAT MAKES SOCIAL INTERACTIONS KIND OF EXCITING IS THAT YOU DON'T KNOW WHAT'S GOING TO HAPPEN?

That's a really good point. Maybe the fabric of human life will necessarily include disappointment and criticism and arguments.

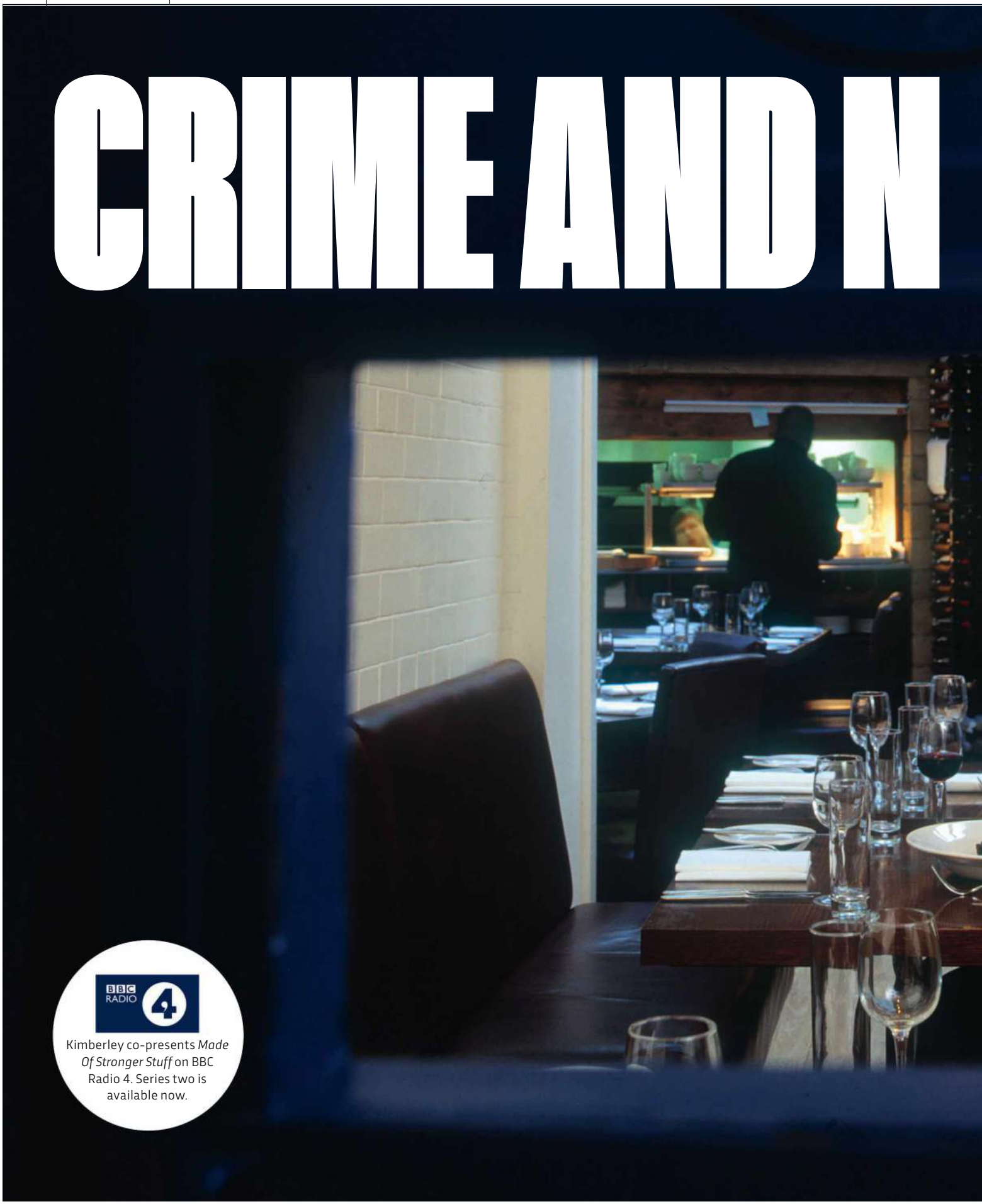
But did you ever see the movie *Bicentennial Man*? Robin Williams plays a robot who becomes, over time, more and more human. He just had the most wonderful qualities and I think almost anyone would want to be a friend of his. So yes, it probably could get boring… I don't know that that's been depicted in any of our sci-fi movies yet. **SF**

DR MICHELLE DROUIN

Michelle is a professor of psychology at Indiana University-Purdue University Fort Wayne. She is fascinated by the potential that AI holds for providing deep emotional, physical and intellectual intimacy. She has worked on a number of projects, including Hanson Robotics' Sophia, the world's first robot citizen.

Her first book, Out Of Touch: How To Survive An Intimacy Famine, *(£22.50, MIT Press) explores current research into intimacy, sex, love, social media and AI.*

CRIME AND N



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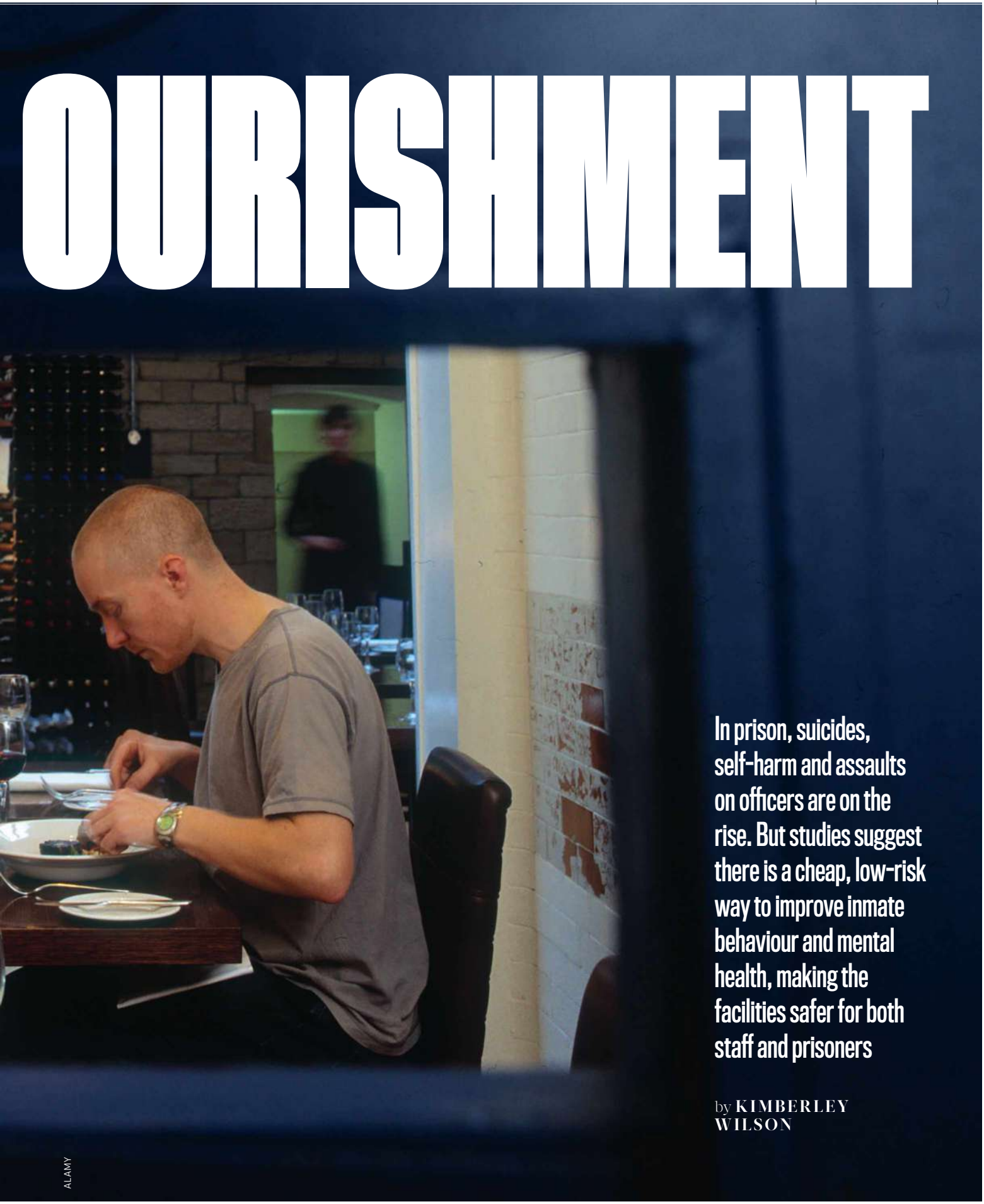


ALAMY

In prison, suicides, self-harm and assaults on officers are on the rise. But studies suggest there is a cheap, low-risk way to improve inmate behaviour and mental health, making the facilities safer for both staff and prisoners

by KIMBERLEY WILSON

Scientific progress is characterised by the transition from the supernatural to the natural, and the mystical to the comparatively mundane. Before the modern era of psychology and neuroscience, mental illness was understood to be evidence of the supernatural: demonic possession, unhappy deities or vengeful curses. Unusual behaviour would be addressed through prayer, penance and exorcism. Towards the end of the Renaissance, when the church's power over civil life began to wane, there was greater acceptance of more mundane causes of emotional distress or unusual behaviour. Though the treatment of mentally ill individuals in 16th-Century asylums could not be called humane, the assumption, at least, was that the causes of illness were natural or physical and they were treated with purges or emetics.

Today, one of the most mundane – but profound – influences on mental health and behaviour emerging in the scientific literature is food and nutrition. While I am not suggesting that nutrition answers all of our questions around the mind and mental health, it is a key and undervalued part of the overall picture and its effects have been repeatedly demonstrated in one environment in particular: prison.

A series of studies have found that improving prisoners' nutrition reduces incidents of violence by, on average, 30 per cent. This is a fascinating and remarkable series of results that should make us think very carefully about the food that we choose for ourselves, feed to our children or provide in our institutions.

THE KIDS AREN'T ALRIGHT

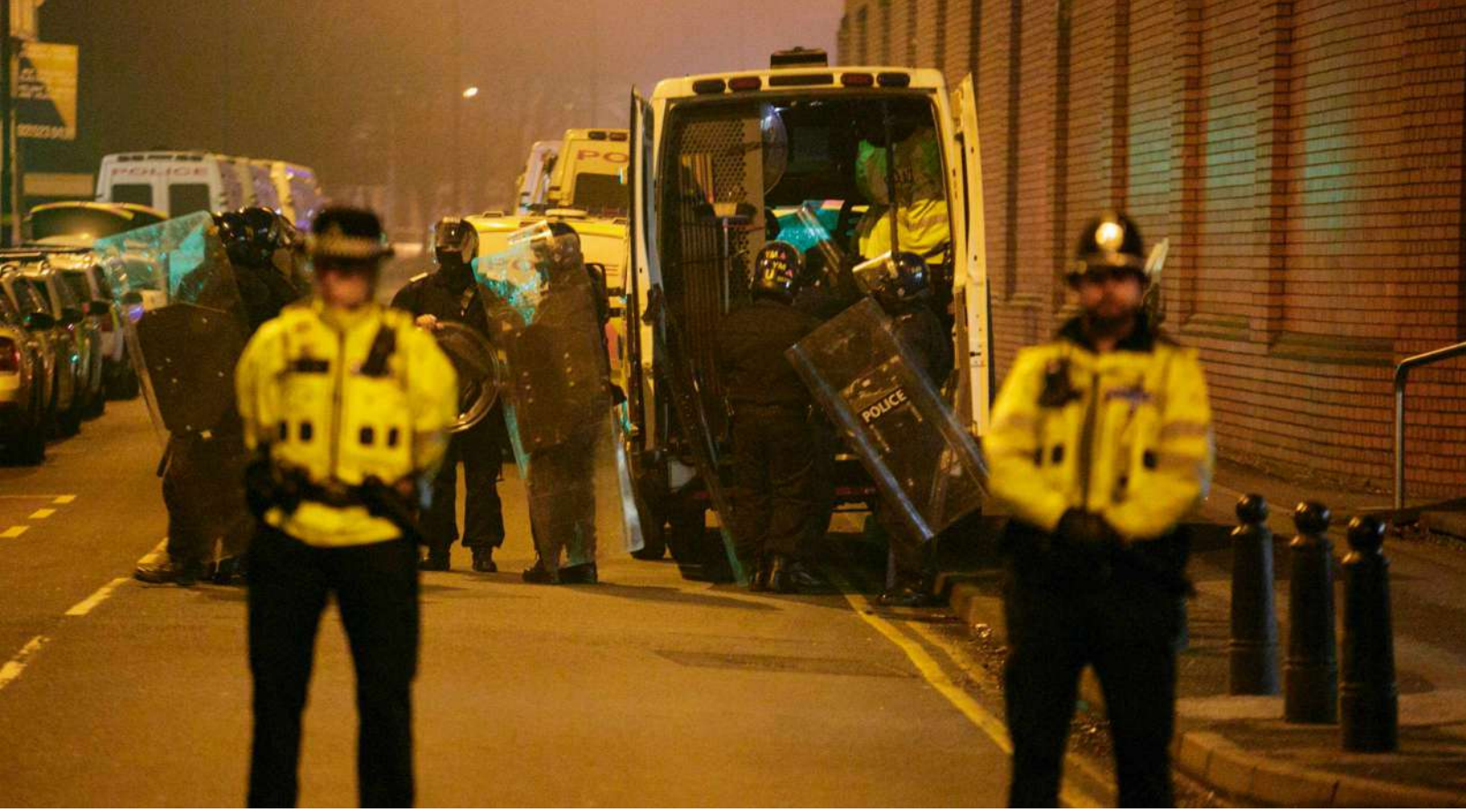
Decades of research have found a relationship between nutritional status and child behaviour. Omega-3 fatty acids make up about 35 per cent of brain cell membranes and are important for neurons to send and receive messages. These dietary fats are therefore crucial during early brain development from conception to two and half years old. In fact, according to a study published in March 2021 in *The American Journal Of Clinical Nutrition*, low omega-3 intake during pregnancy is associated with smaller brain size in childhood. Another research paper published in *The Journal Of Pediatrics* in 2014 found a link between early malnutrition and behaviour in children aged five to six, with those who had low fatty acid intake more likely to show behaviours like physical aggression, defiance and vandalism. These behaviours themselves are a signal that can predict whether a child is likely to take part in antisocial or violent behaviour as an adolescent or adult.

Of course, diet is not the only contributing factor. How a child or young person learns to respond to stress or threats is also a feature of parenting, language ability and attachment style. So can we disentangle the influence of nutrition from these other features? Yes, to an extent. An assessment of 4,000 Dutch toddlers found that bad behaviours in the children were reduced when the mothers had supplemented with folic acid during the first trimester of pregnancy. The protective effect of supplementation was statistically significant, even after controlling for maternal age, educational level, national origin and psychopathology.

In children with ADHD, a fully blinded randomised controlled trial – the gold standard for experiments of this nature – found that a combined multivitamin and mineral (and sometimes omega-3) tablet given for 10 weeks significantly reduced aggression and "hot tempers, fights with other children, [and] explosive angry outbursts".

ADHD is a neurodevelopmental disorder that affects around 5 per cent of children, predominantly boys. Children with ADHD who are unable to modify their behaviour may be over 100 times more likely to be permanently excluded from school, which itself leads to an increased risk of criminal behaviour and incarceration.

BELOW Bethlem Hospital in the 1730s, as portrayed here by artist William Hogarth, at a time when madness was considered to be a result of vices



ABOVE Police prepare to enter Winson Green Prison during riots in 2016

LEFT Images obtained from a serving male prisoner in the UK, showing the meals on otter at dinner

So, poor nutrition in childhood can influence brain development in such a way as to increase the likelihood of violent and aggressive behaviour in later life. And this brings us back to prisons.

PRISON FOOD

There are few regulations on the quality of food in prison. In the UK, The Prison Rules, which is a piece of legislation that governs how prisons are run, stipulates that prison food should be "wholesome, nutritious, well prepared and served, reasonably varied and sufficient in quantity". In reality, this is subject to wide interpretation since terms like 'wholesome' and 'nutritious' have no clinical definition. Additionally, prison food in the UK is provided by private contractors, meaning that profit margins and shareholder returns factor into the variety and quality of food provided. According to nutrition charity the Food Foundation, it costs £5.99 per day for an adult to meet the UK's Eat Well healthy diet recommendations. An average of £2 a day is spent on a prisoner's meals.

"IT COSTS £5.99 PER DAY FOR AN ADULT TO MEET THE UK'S EAT WELL HEALTHY DIET RECOMMENDATIONS. AN AVERAGE OF £2 A DAY IS SPENT ON A PRISONER'S MEALS"

This means that, typically, the meals on offer are highly refined, ultra-processed food of low nutrient density. The standard breakfast pack is composed of a 30g (variety pack size) box of breakfast cereal; sachets of coffee, tea and sugar; a carton of milk; white and sometimes brown bread for toast; jam and margarine. Lunch is usually a white bread sandwich served with crisps, biscuits and a piece of fruit. Images obtained from a serving male prisoner depict the reality of the dinner provided: battered fish and chips, sausages and hash browns, pasty and potatoes (see image above).

Having worked in a large women's UK prison for a number of years, I can verify this was typical of the food on offer. A highly processed diet with little fresh produce is likely to contribute to deficiencies in micronutrients known to be supportive to healthy brain structure and function, such as folate and magnesium (found in leafy green vegetables) and omega-3 fats (found in oily fish).

The discussion around prison nutrition often becomes contentious in relation to philosophical conflicts as to whether the function of prison is rehabilitation or punishment. But whether or not you think offenders deserve quality food, the relationship between improved nutrition and overall prison safety is much less complicated. The UK government's most recent figures show

GETTY IMAGES, ALAMY, UK JAIL TRUTHS/INSTAGRAM X3

that suicides in prison have increased 13 per cent compared to the previous 12 months. In the most recent quarter, self-harm in men's prisons rose by 8 per cent and a whopping 47 per cent in women's. At the same time, the number of assaults on staff rose by 14 per cent. The numbers are growing in the wrong direction, and nutrition could provide a quick and achievable remedy.

ABOVE The diet in UK prisons can be lacking in fresh produce. A daily supplement could help boost levels of essential nutrients, to improve mental health and behaviour

THE PRISON STUDIES

Scientific evidence for the effect of improved nutrition on prisoner violence can be found in what I call 'The Prison Studies'. These are five international nutrition trials that have been carried out in prisons over the last 25 years. The inmates were given supplements of vitamins and minerals, and some received omega-3 too. The studies each reported remarkably similar outcomes of around 30 per cent reductions in violence when prisoner nutrition was improved.

Another trial is now underway to explore the role of omega-3 and prisoner aggression in Australia on the basis of these studies and prior evidence showing a relationship between lower omega-3 status and greater tendency to aggression in Australian prisoners.

The benefit of supplements over whole foods in these studies is that participants do not know whether they are getting the real supplement or the placebo. It's virtually impossible to carry out these studies with actual food; you know whether you are eating an apple or a sausage roll. What is important about these studies is that they were all randomised, blinded and placebo-controlled. This methodology, which aims to reduce the potential for bias in clinical research, is considered the best way to test the efficacy of a treatment. Indeed, it is the 'gold standard' means of discerning whether a drug or other treatment really does what it says on the tin. Finally, there were no reported side effects of taking the supplements, making it a safe intervention. What this indicates is that improved nutrition presents a cheap, low-risk and accessible opportunity to reduce the growing rates of violence in UK prisons. In an era in which we are seeing record levels of self-injury and suicide, this could equate to lives saved, as well as safer prisons for staff.

But how does improved nutrition compare to other treatments? A recent meta-analysis reviewed the impact of psychological treatments (such as anger management and 'thinking skills' courses) for violent offenders. Treatment duration varied from 24 hours to 470 hours and showed that they were not effective at reducing violent incidents in prison compared to controls.

A now-old study showed that treatment with lithium reduced major infractions (including both threats and actual violence) in prison by around 40 per cent. However, the participants could guess whether they were receiving treatment or placebo, introducing a risk for bias, and there was a high dropout rate due to the side effects of lithium treatment, which included nausea, vomiting, dry mouth, tremors and excessive urination.

A preliminary study of a 10-week yoga course found improved behavioural performance. Yet it is not clear whether this would translate to risk of real-world violence. In addition, aggressive men may be more likely to drop out of exercise courses, or be asked to leave due to misconduct.

It therefore seems as if nutritional interventions could offer better outcomes than other treatments, with fewer side effects.

"BETTER NUTRITION IS ACCESSIBLE AND FAST ACTING: IMPROVEMENTS ARE MEASURABLE IN WEEKS NOT YEARS. IT'S ALSO COMPARATIVELY CHEAP"

Independent of violence, improving nutrition in prison could provide other benefits. Up to 90 per cent of prisoners are thought to have a diagnosable mental health condition. In this area, there is a growing scientific consensus on the importance of good nutrition for mental wellbeing. Again, it is unlikely that better food will resolve all of these issues, but it may meaningfully reduce the levels of distress and the burden on prison security and healthcare staff.

It would be naïve to suggest that inadequate nutrition was the leading or sole cause of criminal behaviour. Other known risks include poverty, social deprivation, parental stress and mental ill health, as well as being in the vicinity of other rule-breakers. But of these known risk factors, better nutrition is by far the most accessible and fast-acting: improvements are measurable in weeks not years. It's also comparatively cheap.

It currently costs the UK government over £44,000 to house a single prisoner for a year, up nearly £10,000 since 2015. Following the results of one of the prison studies, published by Dr Bernard Gesch and colleagues in 2002, an economic analysis was commissioned by the Home Office which showed that providing prisoners with supplements would cost around £40 per prisoner per year. That was in 2002, but the popularity of nutritional supplements today has likely lowered those production costs. Providing more fresh (perishable) produce may cost more than the current highly processed fare, but those costs are likely to be offset by savings on security and staff turnover.

For a potential 30 per cent reduction in violence, enhanced physical and mental health, fewer riots and better staff retention, improved nutrition would seem like a worthwhile investment. In addition, costs could be offset through agricultural programmes where food used to feed prisoners is grown on site. Such projects help to provide skills, as well as improved nutrition.

When it comes to making prisons safer for prisoners and staff, improving nutrition really is a no-brainer. **SF**

BELOW Improved nutrition in prisons would reduce violence, making conditions safer for both inmates and officers

by **KIMBERLEY WILSON** *(@FoodAndPsych)*

Kimberley is a chartered psychologist, author, presenter and lecturer with a degree in nutrition. Her book, How To Build A Healthy Brain *(£12.99, Yellow Kite), is out in paperback in March.*

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FROM THE MAKERS OF BBC Sky at Night MAGAZINE

The Astronomer's Yearbook 2022

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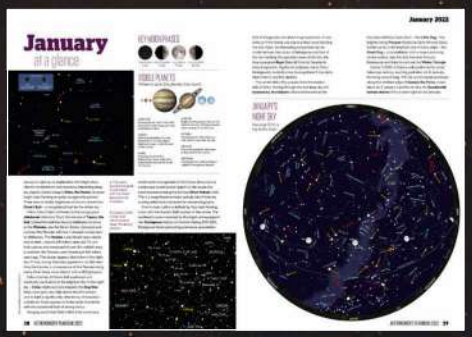
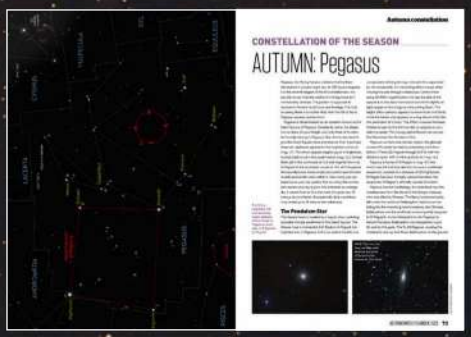
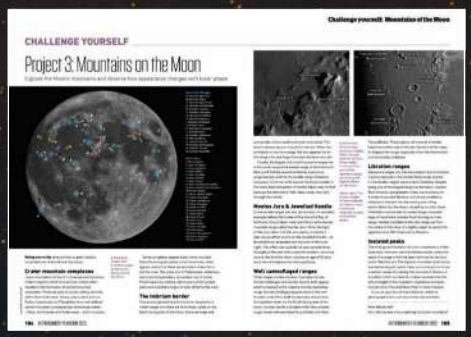


Our month-by-month guide and detailed star charts reveal what to look for and when, from stars and planets to Moon phases and more.



Get to know the stand-out constellations of each season, as we highlight their brightest targets and how to best observe them.



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TERRY HANCOCK

Q&A

YOUR QUESTIONS ANSWERED

... HOW DO SOLID-STATE BATTERIES WORK?
... ARE THERE ANY GENETIC FACTORS THAT AFFECT SEASONAL DEPRESSION?
... WHAT ARE NURDLES?
... HOW DO MACROPHAGES WORK TO KILL BACTERIA?
... COULD ANY CREATURES BLOW FIRE LIKE A DRAGON?
... WHAT'S THE BEST WAY TO MAKE A DECISION?
... HOW ARE ARTIFICIAL GLACIERS MADE?
... HOW DO I CONTROL MY CHOLESTEROL?
... HOW DOES STRIPED TOOTHPASTE ALWAYS COME OUT STRIPED?
... WHAT WOULD IT MEAN FOR BIODIVERSITY ON EARTH, IF THE MOON WAS COMPLETELY BLACK?

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DR HELEN PILCHER
Biologist and science writer

LUIS VILLAZON
Science and technology writer

ILLUSTRATION: DANIEL BRIGHT

JENNY WALKER, SHEFFIELD

IS IT TRUE YOU CAN'T JUST CUT THE MOULDY PARTS OFF FOOD?

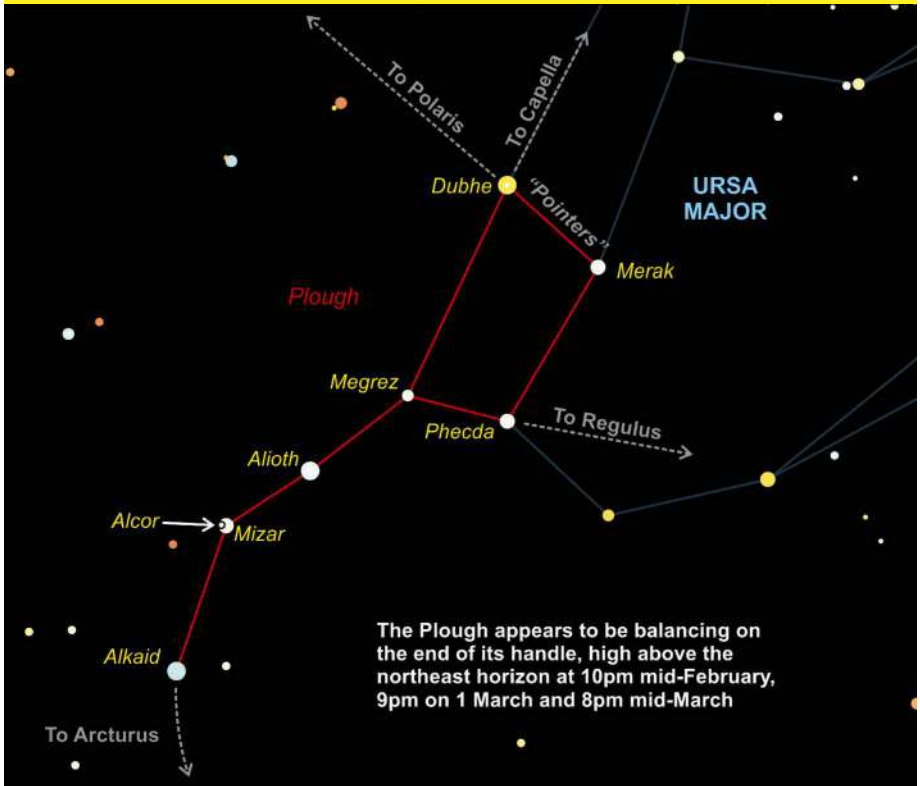
You may think you are carefully eating around the mould, but there are likely to be hidden toxins lurking below the surface.

Different types of moulds grow on food, from *Penicillium* in blue cheese to *Botrytis* on strawberries. Moulds are fungi, some of which produce poisonous substances called mycotoxins. Several hundred mycotoxins have been identified, but about a dozen have a reputation for causing serious health effects, including tremors, muscle weakness, fever and vomiting. Aflatoxins, produced by *Aspergillus* moulds in cereals, spices and tree nuts, are among the most poisonous. They can damage DNA to cause cancer, while large doses can kill by damaging the liver. Thankfully, most mycotoxins are only a health risk if we eat them over long periods.

If the conditions are right for moulds to grow, harmful bacteria may also multiply. Moulds thrive in moist, so foods, such as peaches. They also spread quickly through porous items like bread, creating a network of roots invisible to the human eye, making it best to throw these mouldy foods away.

It is generally advisable only to eat mouldy foods that are designed to be that way, such as blue cheeses. However, there are some exceptions when you can safely slice away mould, including hard cheese, hard salami, and firm fruit and vegetables like carrots and pumpkin. Hard cheese has a low moisture content and a dense structure, meaning that mould is less likely to spread far below the surface. If you are brave enough to remove mould from cheese, slice away a good margin. If a so blue cheese begins to grow different types of mould, throw it away. ***ED***

ASTRONOMY FOR BEGINNERS



HOW TO USE THE PLOUGH AS A SIGNPOST

WHEN: MID-FEBRUARY TO MID-MARCH

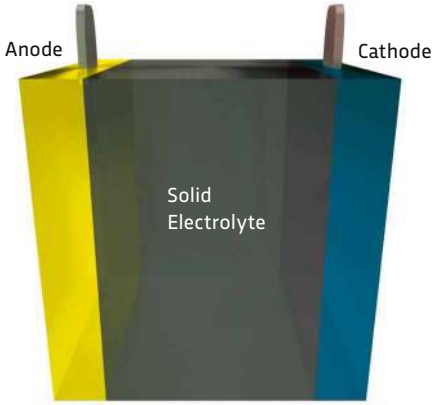
The two most recognisable star-patterns for northern hemisphere sky-watchers are Orion and the Plough. Orion is a constellation representing a mythological hunter, while the Plough is an asterism – an unofficial pattern of stars within Ursa Major the Great Bear.

All stars appear to rotate around two points representing the projection of Earth's rotational axis into the sky: the North and South Celestial Poles (NCP and SCP). The NCP sits above the northern point on the UK's horizon at an altitude equivalent to your latitude. Stars close enough to the NCP will appear to orbit it without setting, a behaviour described as 'circumpolar'.

The Plough is circumpolar from the UK and is known by many names: the Saucepan (la Casserole in France), Charles's Wain, the Big Dipper, the Big Rudder and more. The Plough and the Saucepan are the two most common descriptors in the UK.

Being visible whenever it's dark and clear, the pattern is useful for star-navigation. Imagining it as a saucepan, follow the line of the two stars farthest from the handle, Dubhe and Merak, up with respect to the pan to locate Polaris, the North Star. Polaris almost sits on the NCP and as far as the naked eye is concerned, appears stationary. Dubhe and Merak are known as 'the Pointers'.

Follow the natural arc of the handle away from the pan and eventually you'll arrive at the bright orange star Arcturus, which can be remembered by the mnemonic of "follow the arc to Arcturus". Follow the line of the two stars in the pan nearest the handle down with respect to the saucepan and you'll eventually arrive at Regulus, the brightest star in Leo the Lion; "a hole in the bowl will leak on Leo". Finally, extend the top edge of the pan away from the handle to locate bright Capella in Auriga the Charioteer; "follow the cap to Capella". ***PL***



JOHN AWBERY, VIA EMAIL

HOW DO SOLID-STATE BATTERIES WORK?

Most conventional electric vehicles and mobile phones use lithium-ion batteries, which have an electrolyte gel inside them to separate the positively charged graphite anode from the negatively charged lithium cathode. These are relatively cheap to make but suffer from thermal runaway – heat them beyond a specific temperature and an unstoppable chain reaction causes them to disintegrate in fiery explosions. Solid-state batteries replace the electrolyte gel with a solid material such as ceramic or glass, which makes them less flammable, faster charging, lighter, and higher power. At present, they're still under development and remain costly to manufacture. This may soon change, as companies are spending billions on the development of this new technology. ***PB***

MARY JEVONS, ARMLEY

ARE THERE ANY GENETIC FACTORS THAT AFFECT SEASONAL DEPRESSION?

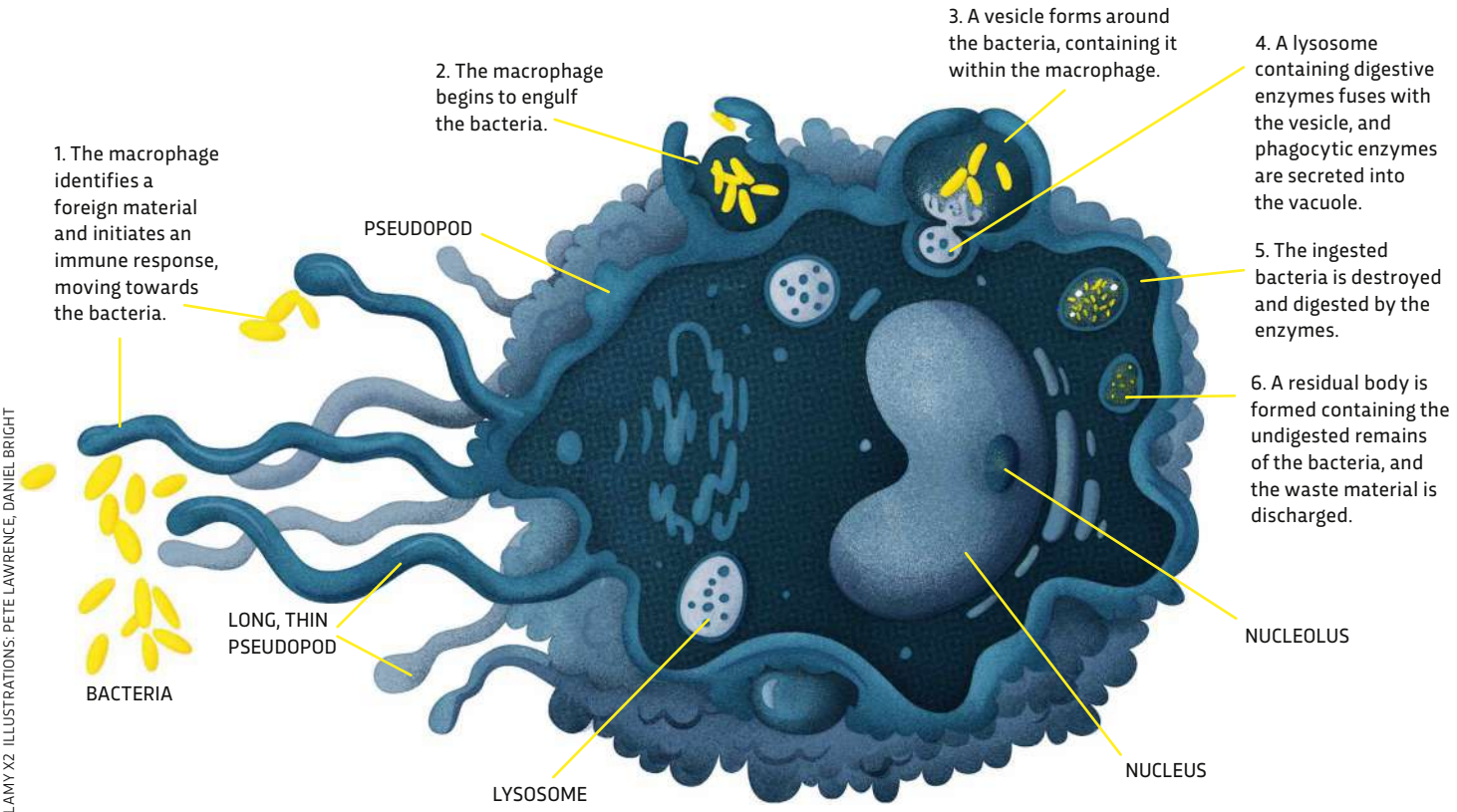
There is preliminary evidence that people with blue eyes are less vulnerable than people with brown eyes to so-called 'seasonal affective disorder' (SAD) – that is, low mood that occurs in the dark winter months. In one study, researchers at the University of South Wales surveyed dozens of students in Wales and in Cyprus and found that those with blue eyes were less likely to describe seasonal effects on their mood. More research is needed, but a tentative theory is that blue eyes have this protective effect because they are more sensitive to light – in turn this inhibits the daytime release of melatonin, a hormone which might be responsible for the lethargy experienced by people with SAD. ***CJ***

MAI HUYNH, WEST MIDLANDS

WHAT ARE NURDLES?

Nurdles are tiny plastic pellets used by the plastics industry. Roughly the same size as a lentil, they are melted down and moulded into a variety of plastic products. But as nurdles are produced and shipped around the world, every year about 230,000 tonnes leak into the wider environment, according to a survey by environmental charity Fidra. One cargo ship spill alone in May 2021 released 1,500 tonnes of nurdles into the Indian Ocean. Like other microplastics, nurdles pose a threat to marine life as they tend to absorb toxic chemicals and can easily be ingested by animals who mistake them for food. ***AFC***

HOW DO MACROPHAGES WORK TO KILL BACTERIA?


1. The macrophage identifies a foreign material and initiates an immune response, moving towards the bacteria.
2. The macrophage begins to engulf the bacteria.
3. A vesicle forms around the bacteria, containing it within the macrophage.
4. A lysosome containing digestive enzymes fuses with the vesicle, and phagocytic enzymes are secreted into the vacuole.
5. The ingested bacteria is destroyed and digested by the enzymes.
6. A residual body is formed containing the undigested remains of the bacteria, and the waste material is discharged.
PSEUDOPOD
LONG, THIN PSEUDOPOD
BACTERIA
LYSOSOME
NUCLEUS
NUCLEOLUS

ALAMY X2 ILLUSTRATIONS: PETE LAWRENCE, DANIEL BRIGHT

PAD SCANLON, VIA EMAIL

COULD ANY CREATURES BLOW FIRE LIKE A DRAGON?

Out of its mouth? No. Out of its backside? Yes! Well, almost. There are no fire-breathing dragons, but there is the bombardier beetle, which ejects a hot, fiery mixture from its butt when threatened. The spray is produced by the reaction between two chemicals; hydroquinone and hydrogen peroxide, which are stored in separate abdominal compartments before coming together with a bang. The resulting heat brings the mixture to almost 100°C and produces gas which drives the expulsion. This means that if a bombardier beetle gets eaten by a toad, it can literally fart its way out of trouble. It lets rip inside the amphibian's belly until the predator vomits it up. ***HP***

CROWDSCIENCE

Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

WHAT'S THE BEST WAY TO MAKE A DECISION?

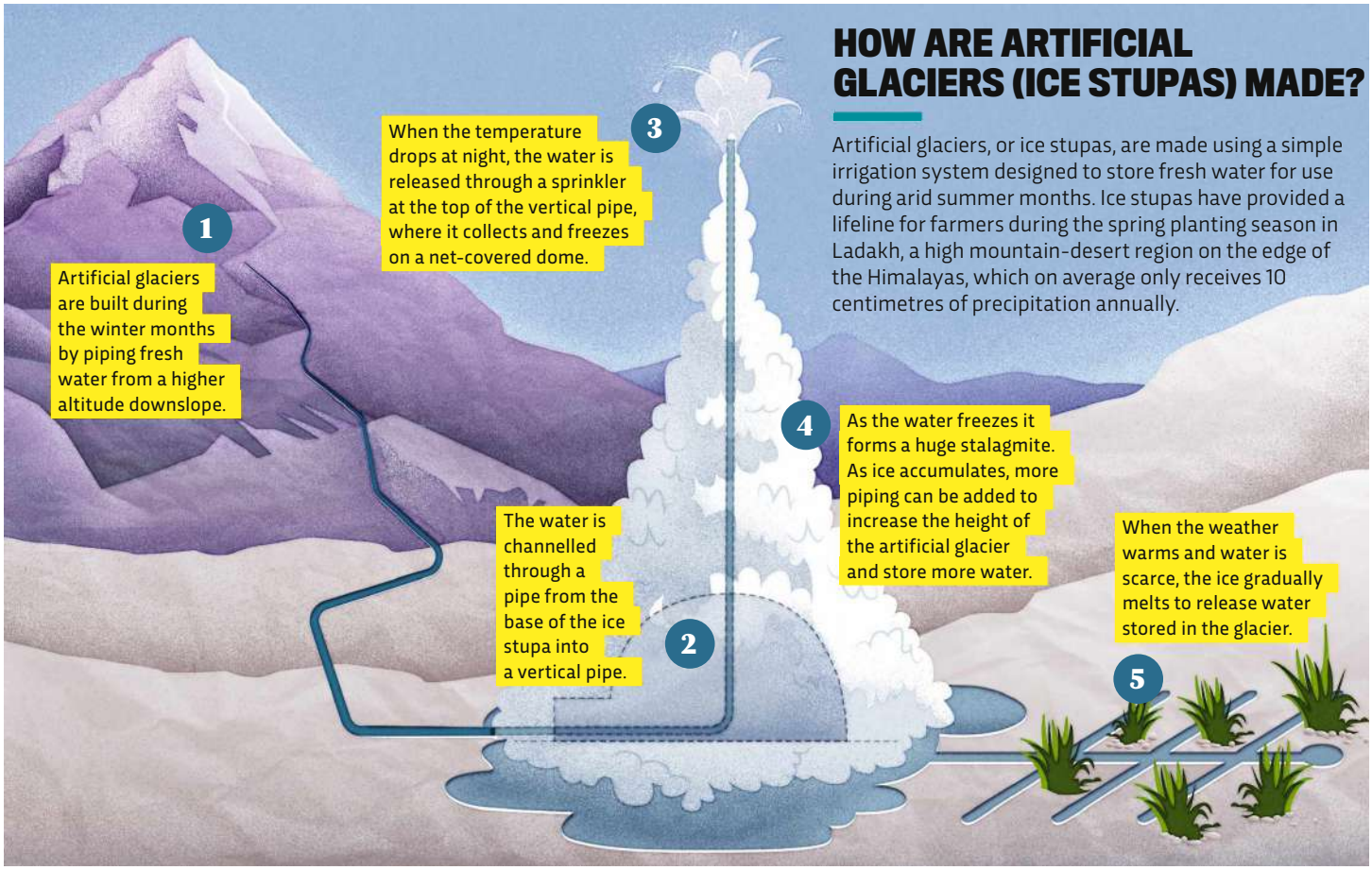
The optimal approach is to ensure you are well informed and to use techniques to overcome the biases of thought and emotion that are known to skew human rationality. So, begin by gathering background information on the decision, making sure you draw on diverse, reputable sources.

Now, one bias that could lead you astray is the 'affective forecasting error'. Essentially, we're poor at anticipating how we'll feel in future situations. To get around this, find out how other people similar to you felt after making a given choice. Another relevant bias relates to 'temporal discounting' – we tend to prioritise short-term gains over long-term consequences. For instance, you might agree hastily to a future commitment (such as a taking on a new project at work or going on holiday with a friend) because the immediate benefits are salient, in terms of kudos or popularity, but you underestimate the investment of time and effort required in the future. When faced with these kinds of scenarios, try to imagine how you would feel if the commitment were imminent – if you had to work on the project this week, or get ready for the holiday next weekend.

Once you've completed the above steps, it is a good idea to compile a list of pros and cons of your options and to use a systematic scoring system to ground your decision. That said, you don't want to completely neglect your gut instincts or tacit knowledge. So, do your scoring and then sleep on the decision and see how you feel in the morning. That way you'll have drawn on a healthy mix of mind and heart before you make the leap. *CJ*

Try to picture the long-term consequences of a decision, without ignoring your gut feeling

NATURE PRODUCTION/NATUREPL.COM, ALAMY, GETTY IMAGES ILLUSTRATION: DANIEL BRIGHT

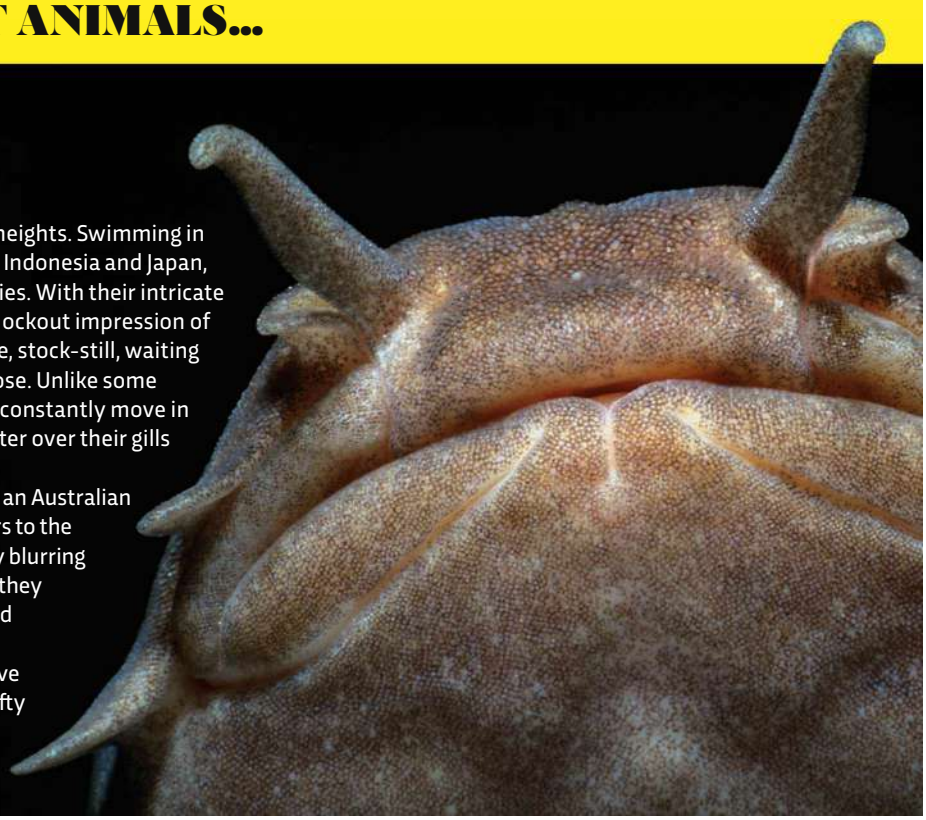

1
Artificial glaciers are built during the winter months by piping fresh water from a higher altitude downslope.
2
The water is channelled through a pipe from the base of the ice stupa into a vertical pipe.
3
When the temperature drops at night, the water is released through a sprinkler at the top of the vertical pipe, where it collects and freezes on a net-covered dome.
4
As the water freezes it forms a huge stalagmite. As ice accumulates, more piping can be added to increase the height of the artificial glacier and store more water.
5
When the weather warms and water is scarce, the ice gradually melts to release water stored in the glacier.

HOW ARE ARTIFICIAL GLACIERS (ICE STUPAS) MADE?

Artificial glaciers, or ice stupas, are made using a simple irrigation system designed to store fresh water for use during arid summer months. Ice stupas have provided a lifeline for farmers during the spring planting season in Ladakh, a high mountain-desert region on the edge of the Himalayas, which on average only receives 10 centimetres of precipitation annually.

NAT RE'S WEIRDEST ANIMALS...

THE WOBBEGONG



The wobbegong shark takes camouflage to new heights. Swimming in the warm, shallow waters surrounding Australia, Indonesia and Japan, this master of disguise comes in 12 different species. With their intricate markings and pebbly hues, these animals do a knockout impression of the sea floor, where they spend most of their time, stock-still, waiting to ambush any hapless morsel that swims too close. Unlike some other shark species, wobbegongs do not need to constantly move in order to breathe. Instead, they actively pump water over their gills with their cheek muscles.

The word 'wobbegong' is thought to come from an Australian Aboriginal word meaning 'shaggy beard' and refers to the wispy tassels that frame their enormous chops. By blurring the lines between the shark and its surroundings, they enhance the camouflage effect, and can be wiggled suggestively to lure curious prey, such as bottom-dwelling fish and octopuses. Wobbegongs also have strong lower fins which enable them to 'walk'; a nifty trick if the fish find themselves landlocked in a rockpool when the tide has gone out. ***HP***

DEAR DOCTOR...

HEALTH QUESTIONS DEALT WITH BY *SCIENCE FOCUS* EXPERTS

HOW CAN I CONTROL MY CHOLESTEROL?

Cholesterol is a type of fat, called a lipid, which is present in the blood. It's a waxy substance, and your body needs cholesterol to build healthy cells, but too much can lead to the build-up of fatty deposits in your blood vessels, increasing your risk of heart disease.

Diet is a key contributor to high cholesterol. The key is to cut down on foods with saturated fat, like cheese, biscuits, cakes, butter, pies, sausages, coconut oil and fatty meats. Eating more foods with unsaturated fats can help, such as avocado, vegetable oils, nuts, and oily fish. There are good diet sheets available on the British Heart Foundation and NHS websites with more detail, which might be worth pinning on the fridge as a reminder.

Exercise can also help lower cholesterol, even as simple as using the stairs instead of the lift, taking a brisk walk or doing two-minute bursts of activity at home, such as star jumps, can make a difference. Stopping smoking and reducing alcohol to safe limits (14 units a week) can also lower cholesterol.

If lifestyle changes alone don't work, then sometimes medications (called statins) are needed. These are usually taken once a day for life. These can be very effective at lowering cholesterol, and despite sometimes getting a bad press, often they only have few side effects. One widely reported side effect is muscle pain, but most people don't experience any at all. Statins have been around for over 30 years, have been prescribed to millions of people, and are estimated to save 7,000 lives each year in England. ***NM***

TOP 10 BOOZIEST COUNTRIES

1 LATVIA 13.19*

2 MOLDOVA 12.85*

3 GERMANY 12.79*

4 LITHUANIA 12.78*

5 IRELAND 12.75*

6 SPAIN 12.67*

7 UGANDA 12.48*

8 BULGARIA 12.46*

9 LUXEMBOURG 12.45*

10 ROMANIA 12.34*

* AVERAGE CONSUMPTION OF PURE ALCOHOL IN LITRES PER YEAR AMONG ALL ADULTS AGED 15+

TINA CHAPMAN, COLCHESTER

HOW DOES STRIPED TOOTHPASTE ALWAYS COME OUT STRIPED?

The answer does not lie with clever engineering, but with carefully designed pastes. Coloured pastes are loaded into the tube separately but are not stored in compartments. The pastes are designed to have just the right viscosity or thickness so that they don't mix, acting like solids inside the tube but flowing smoothly when you squeeze or pump it. They have similar flow characteristics to ketchup, which only gets moving with a good shake or a squeeze. In some toothpastes, a nozzle at the top of the tube has separate holes for di erent colours, ensuring they emerge as neat stripes. ***ED***

QUESTION OF THE MONTH

JAKOB KAYE, DUMFRIES AND GALLOWAY

WHAT WOULD IT MEAN FOR BIODIVERSITY ON EARTH, IF THE MOON WAS COMPLETELY BLACK?

WINNER

The winner of next issue's *Question Of The Month* wins an **Ember Mug²**, worth £99.95. This smart mug allows you to set the perfect temperature for your hot drink, which it maintains for up to 90 minutes. You'll never cry over a cold, forgotten tea again!
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A matt black Moon would still raise tides but would pass almost invisibly across the sky. Apart from the variation between the height of spring and neap tides, it would be impossible to tell the phase of the Moon. This circalunar rhythm is a very important timing signal that many creatures use to synchronise their behaviour. Corals on the Great Barrier Reef, for example, use the full Moon as the trigger for their annual mass spawning. This ensures that all the polyps have their eggs and sperm in the water at once, which increases the chance of successful fertilisation. Birds also use the lunar cycle to synchronise migrations. For example, the seabird Barau's petrel arrives at its breeding ground on the island of Réunion, in the Indian Ocean, at a different time each year depending on the weather and feeding conditions, but all the birds always arrive together on a full Moon.

What makes the full Moon so useful as a timing cue is that its brightness dramatically increases on the night of the full Moon itself, compared with the nights on either side. This is due to the opposition effect, where shadows on the surface of the Moon (cast by craters and mountains) suddenly disappear when the Moon is lit directly from the front.

Moonlight is more than just a clock though. Even though it is less than one-thousandth of 1 per cent as bright as daylight, it is still 1,000 times brighter than starlight alone. Without the help of moonlight, nocturnal animals would be restricted to those able to navigate by touch or by echolocation. The earliest mammals appeared when the daylight hours were dominated by dinosaurs. Mammal vision was, and still is, specially adapted to work well in moonlight. Without the ability to operate at night, mammals might not have evolved at all! *LV*

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

GETTY IMAGES X2 ILLUSTRATIONS: DAN BRIGHT

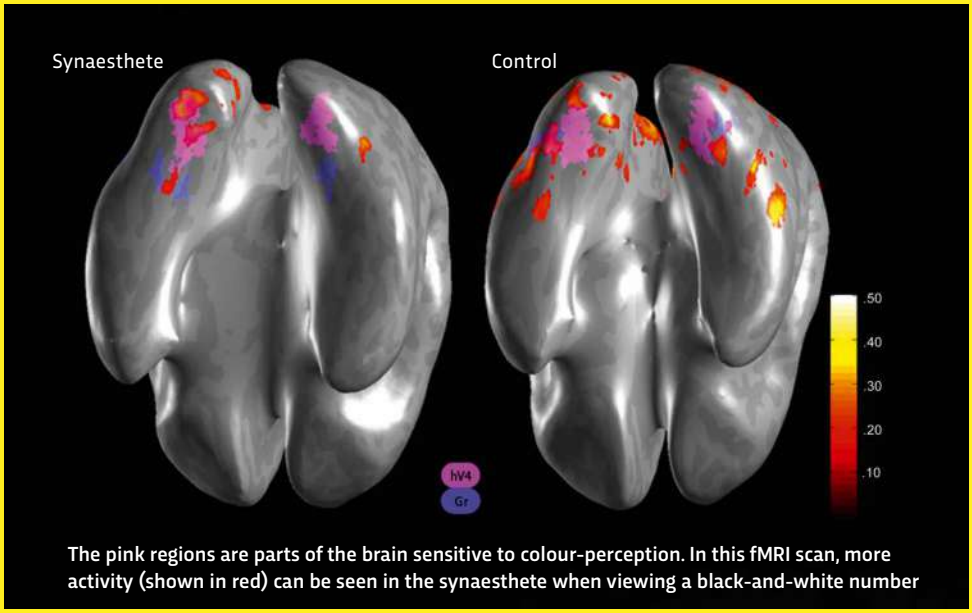
THE EXPLAINER

SYNAESTHESIA

WHAT IS SYNAESTHESIA?

Synaesthesia is a perceptual phenomenon where stimulation of one sense triggers experiences in another sense. For example, a synaesthete might see colours when music plays, or taste flavours when they speak different words. The word synaesthesia originates from the Greek words 'syn' for union and 'aesthesis' for sensation, literally translating to 'a union of the senses'.

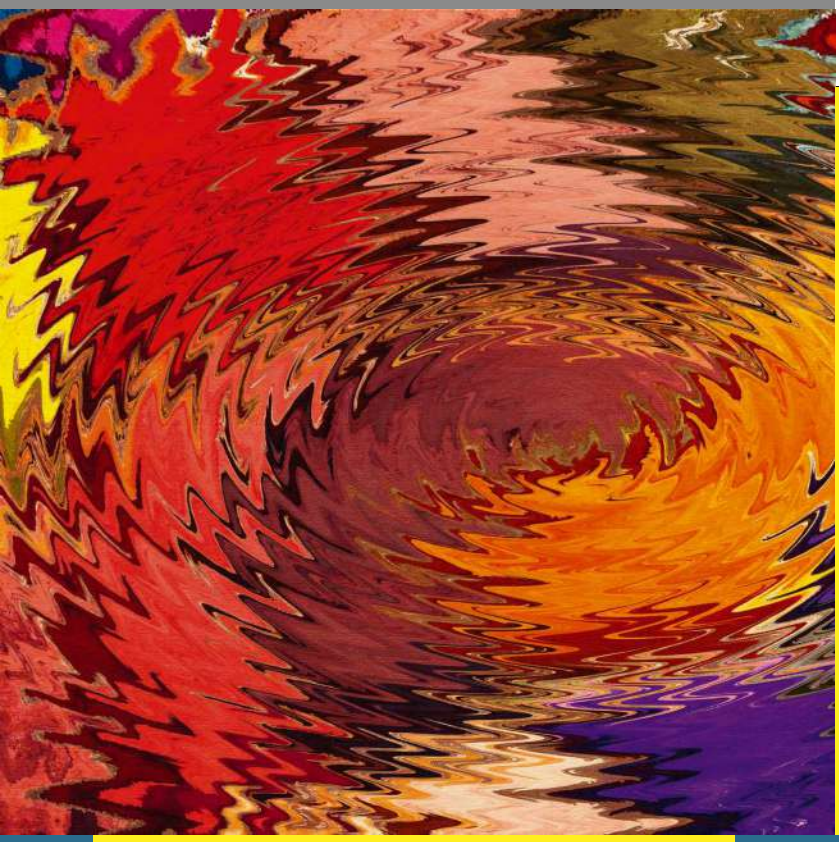
There are over 70 types of synaesthesia, which cause associations between different types of sensory input, but what they all have in common is that the associations are involuntary, present from early childhood, and remain consistent throughout life. It is thought that synaesthesia is caused by extra connectivity between sensory regions of the brain, so stimulation of one sense cross-activates the other. In the 1990s, sound-colour synaesthetes were blindfolded and put into an fMRI scanner. They displayed activity in visual regions of the brain when sounds were played, a pattern not seen in non-synaesthetes. We now know that white matter, which connects different brain regions, is organised differently in synaesthetes' brains, and they have more grey matter in regions responsible for perception and attention. We are all born with many cross-connections between brain regions, but for most of us these are pruned during early development. One theory is that synaesthetes' brains go through less pruning, so they experience interlinked senses throughout life.



The pink regions are parts of the brain sensitive to colour-perception. In this fMRI scan, more activity (shown in red) can be seen in the synaesthete when viewing a black-and-white number

WHEN WAS IT DISCOVERED?

Greek philosophers may have been the first to examine the phenomenon in the 17th Century, when they pondered whether colour was a physical property of music. However, the first documented synaesthete was Georg Tobias Ludwig Sachs, an Austrian physician who wrote about his own experiences of coloured words and music in 1812. Interest in the phenomenon faded during the 19th Century and synaesthesia wasn't formally recognised as a neurological condition until the 1980s. Since then, researchers have begun to unravel the developmental, neurological and psychological roots of synaesthesia, but many questions remain.



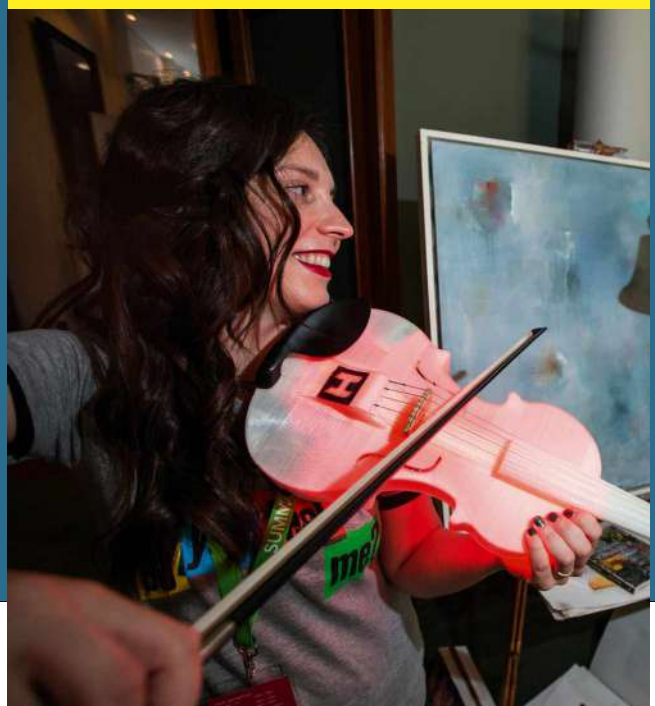
HOW DO I KNOW IF I HAVE IT?

Research by Prof Jamie Ward and Prof Julia Simner at the University of Sussex has found that around 4 per cent of people experience one of the three most common types of synaesthesia. A person with lexical-gustatory synaesthesia might describe words or numbers as small droplets of taste and texture on their tongue, while people with mirror-touch synaesthesia often describe tingling, heat, or pressure sensations in their own bodies when they see a person being touched. Other synaesthetes describe visual illusions such as shapes or auras in front of them when they hear words or music. If any of this sounds familiar, you might have synaesthesia!

Synaesthesia often clusters in families, suggesting a genetic component, but it isn't as simple as there being a single gene 'for' synaesthesia. Research led by Dr Simon Fisher at the Max Planck Institute for Psycholinguistics in the Netherlands has identified six genetic variants associated with sound-colour synaesthesia that are involved in brain connectivity and are expressed in both the visual and auditory regions of the brain.

WHAT SENSES DOES IT AFFECT?

Synaesthesia can connect any two sensory experiences you care to name (and many you can't). Some of the most common include seeing coloured letters or numbers (grapheme-colour synaesthesia), seeing colours when you hear sounds or music (chromaesthesia), and tasting words (lexical-gustatory synaesthesia). The exact associations vary between people — one synaesthete might describe the letter 't' as red, another as blue — and they seem to be learned during childhood. For example, synaesthetes often describe letter-colour associations that match the colours of childhood toys or games.



DOES IT HAVE ANY BENEFITS?

Synaesthetes are more likely to enjoy creative activities due to the richer sensory experience it gives them, and people often report channelling their unusual sensory experiences into art and music. Musicians Pharrell Williams, Mary J Blige and Lady Gaga claim to have chromaesthesia (seeing colours when listening to sounds), while physicist Richard Feynman's grapheme-colour synaesthesia (seeing coloured letters and numbers) helped him write and remember equations. There may be other benefits too. For example, grapheme-colour synaesthesia has been linked to improved memory and faster information processing. In children, it is associated with a larger vocabulary and higher literacy. Research shows that synaesthetes enjoy an early boost to certain cognitive abilities that is maintained throughout life; elderly synaesthetes show relatively youthful memory abilities.

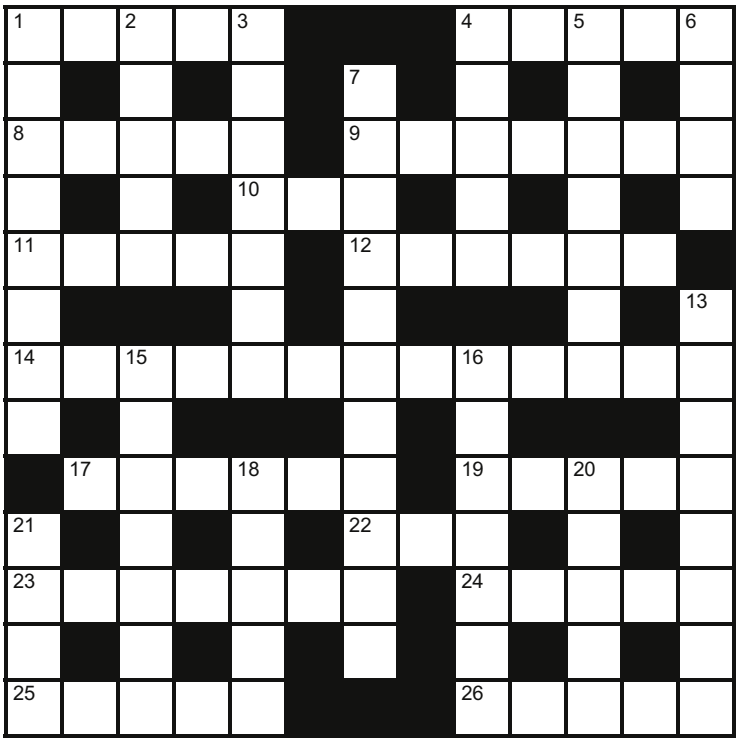
Although synaesthesia is usually present from childhood, there is evidence that non-synaesthetes can learn some sensory associations, and in rare cases, people have developed synaesthesia after brain injury. Some scientists think that training people to associate different senses could help protect against memory decline with age. Researchers are also investigating whether trained synaesthesia can help improve conditions such as autism, dyslexia, and ADHD.

by DR CLAIRE ASHER
Claire is a freelance science writer, performer and comedian

ALAMY, SHUTTERSTOCK, GETTY IMAGES X2, GEOFFREY M BOYNTON/A CYRUS ARMAN/THE SALK INSTITUTE FOR BIOLOGICAL STUDIES

CROSSWORD

PENCILS AT THE READY!



ACROSS

1 Had torn round cape when necessary (2,3)
4 Virile doctor going round a church (5)
8 Amusing soldier found in damp places (5)
9 Some dairy has hog running around in tent (7)
10 Limit international appearance (3)
11 I care about heather (5)
12 Initially organise meeting by word of mouth (6)
14 After development, promote creche's cell (13)
17 Blues composition about old game (6)
19 Not sure when a Republican's removed a member of the family (5)
22 One politician is a mischievous devil (3)
23 A victory – scoundrel rings about fruit (7)
24 Bone puts excellent section back (5)
25 Artist to rely ultimately on material (5)
26 Start to distribute a cut – curious gold coin (5)

DOWN

1 Scale for construction outside (8)
2 Back with current language (5)
3 City that was elegant in the past (7)
4 Graduates taking note – that's hot stuff (5)
5 Husband and wife on time for some poetry (7)
6 Curse out of loathing (4)
7 Honey points out low blood pressure (11)
13 Tear out some information on interesting object (8)
15 Come on – wasted year to get wealth (7)
16 Pure chaos – Edward ttared up (7)
18 Memorise renal layout (5)
20 Youngster in charge of a geometric shape (5)
21 Brace gets fix without engineers (4)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

AN IMMUNE SYSTEM FOR THE PLANET

GETTY IMAGES

PLUS

CROW FUNERALS

Dr Kaeli Swift tells us about the weird world of crow death rituals. At least they don't need to buy any black clothes, eh?

ASTRONOMY FOR BEGINNERS

How to spot the Hydra constellation in the night sky.

ON SALE 16 MAR

SF

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POPCORN SCIENCE

How realistic is Batman?

Could any of us (with a suitably wealthy background) become Gotham's caped crusader?

by STEPHEN KELLY

With no superpowers to speak of, Batman is often held up as one of comic books' more realistic heroes. He does not possess super strength, nor can he fly or shoot lasers out of his eyes. He's just a simple traumatised man with a simple crimefighting dream – and billions of dollars. In theory, this should make him the easiest superhero to aspire to, but according to neuroscientist and martial arts expert E Paul Zehr, author of *Becoming Batman: The Possibility Of A Superhero,* the caped crusader is not as ordinary as he looks…

BAT-SHAPE

If Batman was real, he would be the greatest athlete who ever lived. "He's a NASCAR driver, a super strong fighter, an acrobat, skilled in free-climbing and parkour," says Zehr. "But it's impossible to be a master of all those things. It's why a marathon runner looks different to a power lifter – on a physiological level those disciplines are pulling you in different directions." According to Zehr, it would take almost 18 years to achieve Batman's physical aptitude, and he would need to eat at least 4,000 calories a day to maintain it.

CALENDAR MAN

But those 18 years would not consist of just working out. Batman does not kill or use guns. It takes a lot of skill and training to fight without fatally injuring people.

"When you're in a physiologically stressful situation, your motor skills go down," says Zehr. "Batman has to perform in the most demanding situations possible without the compromised motor skills that would lead to him accidentally killing someone. That takes a lot of work."

BAT-BREAKING LABOUR

It won't be the Joker who eventually takes down Batman, but his gruelling collection of injuries. "You've got someone who is constantly picking up knocks from fighting," Zehr explains. "Thousands of small repetitions and stresses can lead to failure. He's probably going to have tendonitis and arthritis. He will pay for his head injuries too. Eventually he's going to be so depleted by chronic injuries he's gonna be like an athlete who can't compete any more."

But surely his suit would protect him? "Even if you're shot while wearing Kevlar, that's still going to break bones."

THE DARK NIGHT

By day, he is billionaire playboy Bruce Wayne; by night, he is a man who dresses up as a bat. But when does that leave him time to sleep? "Folks who are habitually sleep-deprived suffer from a reduction of cognitive flexibility," says Zehr. "Their critical thinking skills are not as good; they have memory issues." Batman could take microsleeps, but that would only be a short-term strategy. "All kinds of organ systems, including spinal cord excitability for reflexes, are tied to a circadian cycle based on daylight," he says. "We're animals. And as animals, we go to sleep when it's dark out."

TWO-FACE

Being Batman involves more than just punching mentally ill people – it means keeping your identity a secret. This, says Zehr, is difficult not only from a practical perspective, but also a neuroscientific one. "From brain imaging, we know that it's easier for you to tell the truth. It involves less activity in different places because when you're lying, you're thinking about the lie and the thing that's the truth. For somebody like Batman, that becomes a big problem because there's already so much effort everywhere else. It becomes hugely draining." SF

VERDICT
His sleep-deprived schedule and countless fights with thugs would leave him too knackered to keep Gotham safe.

by STEPHEN KELLY *(@StephenPKelly)*
Stephen is a culture and science writer, specialising in television and film.

ILLUSTRATIONS: ADAM GALE MAIN ILLUSTRATION: JOE WALDRON

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